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The University of Michigan, Ann Arbor

Short-Term Memory for Quantitative Information from Three Kinds of Visual Displays

VICKI V. R. COHEN

Technical Report No. 28

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13. ABSTRACT
A series of four experiments was conducted to investigate whether the nature of a visual display affects short-term memory for numeric information extracted from it. Three different kinds of displays were chosen for study: a digital counter, a moving scale and a moving pointer display. Experiment I examined reading performance using the moving scale and moving pointer displays. The results of this experiment, in which the moving scale yielded superior performance, provided baseline data with which to judge future performance and also enabled a judicious choice of exposure durations for the subsequent experiments. In Experiment II the Brown-Peterson paradigm with varied retention intervals was used to examine the short-term memory for quantitative information from the three kinds of displays. In general, the digital counter yielded the best recall performance, followed by the moving pointer and moving scale displays in that order. Analysis of the obtained recall errors suggested that when Ss were attempting to recall information from the moving pointer display, they were able to augment the verbal information in memory with non-verbal pointer position information. Experiments III and IV were between- and within-subjects designs which tested this hypothesis using the Brown-Peterson paradigm with two different interpolated tasks, one of which interfered with the retention of verbal information and the other which interfered with the retention of both verbal and non-verbal information. The differences in error patterns obtained in Experiment II between the moving pointer and moving scale displays were again obtained when the interpolated activity was considered to be causing only verbal interference. However, this difference was abolished or considerably lessened when the interpolated activity was one that interfered with both verbal and non-verbal memory. Thus there was support for the hypothesis that Ss are able to utilize both non-verbal and verbal information in the recall of quantitative information from a moving pointer display.

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THE UNIVERSITY OF MICHIGAN

COLLEGE OF LITERATURE, SCIENCE AND THE ARTS

DEPARTMENT OF PSYCHOLOGY

SHORT-TERM MEMORY FOR QUANTITATIVE INFORMATION FROM THREE KINDS OF VISUAL DISPLAYS

Vicki Vivienne Rhona Cohen

HUMAN PERFORMANCE CENTER--TECHNICAL REPORT NO. 28

June, 1971

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PREFACE

This report is an independent contribution to the program of research of the Human Performance Center, Department of Psychology, on human processing and retrieval, supported by the Advanced Research Projects Agency, Behavioral Sciences, Command and Control Research, under Order No. 461, Amendments 3 and 5, and monitored by the Behavioral Sciences Division, Air Force Office of Scientific Research, under Contract No. AF 49(638)-1736.

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ABSTRACT

A series of four experiments was conducted to investigate whether the nature of a visual display affects short-term memory for numeric information extracted from the display. Three differents kinds of displays were chosen for study; a digital counter, a moving scale and a moving pointer display. In Experiment I reading performance was examined using the moving scale and moving pointer displays. The results of this experiment, in which the moving scale yielded superior performance, provided baseline data with which to judge future performance and also enabled a judicious choice of exposure durations for the subsequent experiments. In Experiment II the Brown-Peterson paradigm with varied retention intervals was used to examine the short-term memory for quantitative information from the three kinds of displays. In general, the digital counter yielded the best recall performance, followed by the moving pointer and moving scale displays in that order. An analysis of the recall errors obtained suggested that when Ss were attempting to recall information from the moving pointer display, they were able to augment the verbal information in memory with non-verbal pointer position information. Experiments III and IV were between- and within-subjects designs which tested this hypothesis using the Brown-Peterson paradigm with two different interpolated tasks, one of which interfered with the retention of verbal information and the other which interfered with the retention of both verbal and non-verbal information. The differences in error patterns which were obtained in Experiment II between the moving pointer and moving scale displays were again obtained when the interpolated activity was considered to be causing only verbal interference. However, this difference was abolished or considerably lessened when the interpolated activity was one that interfered with both verbal and non-verbal memory. Thus there was support for the hypothesis that Ss are able to utilize both non-verbal and verbal information in the recall of quantitative information from a moving pointer display.

CHAPTER I

INTRODUCTION

Many man-machine systems incorporate visual information displays from which the operator must read off information required to maintain successful operation of the machine. In many systems the operator must make a substantial number of quantitative readings from the same display. Thus the question of which type of display to use in a particular system is an extremely important one, for each type of display has its own distinct advantages and disadvantages. Since World War II much research has been directed towards evaluating visual displays and trying to determine for which systems one display is superior to another. One approach to this problem has been to examine reading performance using different types of displays. Two main measures have been used: a) The accuracy with which a display can be read and b) The speed of reading the display in terms of reaction or response times. Various investigators (Sleight, 1948; Christensen, 1952; Elkin, 1959) have evaluated displays using this method and they tend to concur in finding that for both speed and accuracy, reading a moving scale display yielded superior performance to reading a moving pointer display. While these methods provide an indication of how much processing is required to read a particular display, they only tell one side of the story as they consider the reader as little more than an optical scanner. In order to make more realistic evaluations of visual displays, it is preferable to devise methods of investigation in which man is more actively processing

the information rather than merely reading it off the display and doing nothing with it. This limitation in previous studies was mentioned by Graham (1954) [as cited in Rolfe (1965)] who discussed some of the reading experiments and then noted that

> ". . .The criteria of good design employed were the speed and accuracy with which the subjects could read the display. This however is only one half of the problem. Very often the operator has to translate what he sees into an appropriate action."

Clearly it is not sufficient to use only the very simplest task to evaluate a display that is part of a system. Since the display is an element of the system it is highly likely that the information that is extracted from the display will be used subsequently in system operations. One thing lacking in many of the early studies was the failure to consider the fate of the information after it had been read off the displays.

Once the information is read off the display it is retained in the short-term memory of the system operator where it may remain available for subsequent use. The question which the present program of research attempted to answer was "How, if at all, is short-term memory for quantitative information dependent upon the type of display from which it comes?" From a practical standpoint, information on how well readings are remembered is valuable because a machine operator must often read a display, store the information, and use it at some later stage in operations. Consider the case in which the operator reads off the oil pressure at the start of an operation. Towards the end of the operation he reads the pressure again in an attempt to determine to what extent the pressure has changed as a result of the system's operations.

In order to find out what the change is, he must retain the first reading in his memory so that he is able to compare it with the subsequent reading and ascertain the magnitude of the change. The navigator of an aircraft might similarly resort to his short-term memory in trying to reconstruct the routing of the airplane at some later stage in flight operations. Since the information extracted from a display is used in the operation of the system it becomes important to examine the retention of information read off a display. It is necessary to ascertain whether there are differences in the accuracy of recall from display to display and in the event of recall errors, the nature of these errors.

In considering whether there might be differences, both qualitative and quantitative, in the memory for information from different kinds of displays, it is interesting to examine the ways in which the displays differ and how such differences might manifest themselves in memory. Elkin (1959) has demonstrated that for qualitative reading in which less precision is required, performance with a moving pointer display is superior to that with a moving scale display because even a glance at the moving pointer display tells the reader roughly the value of the reading. This difference between the two displays is also evident in the error profiles obtained with readings from brief exposures. The errors made when reading a moving pointer instrument are usually small, e.g., the final digit is misread; while large errors are more frequent in reading a moving scale display. Clearly the existence of a pointer position is a physical difference between the moving pointer

and the moving scale displays that has the potential for conveying additional information. It was considered possible that the pointer position information present in the moving pointer display, could be used by system operators to augment the verbal information in retention of the display reading. Recently a growing body of experimental evidence has accumulated which suggests the possibility of different memory stores for verbal and non-verbal material or at least different forms of stimulus encoding. Margrain (1967) presented pairs of digits, one aurally (verbal), one visually, for recall, and reasoned that if all incoming information was stored verbally, then input modality should cause no differences, and also that interpolated tasks using different modalities should not have differential effects depending on stimulus modality. However, she found that the retroactive interference due to the interpolated task was modality specific and explained her results in terms of two different and independent short-term stores, one visual and the other acoustic. Her results cannot easily be accommodated within the theories of short-term memory that maintain that the stimulus, whether presented visually or aurally, is encoded in some verbal or acoustic form shortly after presentation. The claim that her results are evidence for modality-specific storage is perhaps better stated less strongly as demonstrating the possibility of non-verbal encoding in short-term memory. The experimental approach utilizing material from various modalities and drawing conclusions based on how such material interferes with memory has also been used by Brooks (1968). He presented data which support the hypothesis that verbal and visual (or what he calls "spatial")

information are processed in distinct modality-specific manners. He required Ss to signal information about previously memorized material in one of two ways, either by speaking or by using spatially monitored output. The material about which the Ss had to signal information was either a sentence or a line diagram. He demonstrated that while a person was recalling a line diagram, he could more readily signal information about that diagram by speaking than by using spatially monitored output. In general, he found that when spatial memory was being used, recall was most readily disrupted by concurrent spatial activity and that when verbal memory was involved, recall was most readily disrupted by concurrent verbal activity.

It is quite possible that the first piece of information that an operator extracts from a moving pointer display is the position of the pointer. Several authors have suggested that the analysis of incoming information takes place at various levels; indeed the work on selective attention (Treisman, 1969; Moray, 1959; Cherry, 1953) provides much evidence for this concept. Investigators have found that when S shadowed a message coming in at one ear, he was only able to notice the grossest physical properties of the message to the other ear. One theory to account for these findings suggests that the incoming information may be analyzed in a hierarchical fashion (Neisser, 1967). At the lowest level of the hierarchy the analysis is purely physical, while higher up, the semantic content is analyzed. It is proposed that an S may select the message to which he will attend on the basis of gross physical features and that the message that does not meet the

established requirements is attenuated so that the selected message may receive more concentrated attention. Support for such hierarchical analysis schemes is forthcoming not only from these auditory attention studies, but also from some of the investigations of visual search that suggest a preattentive stage in which crude physical features are considered (Neisser, 1967). In addition Posner and Mitchell (1967) found that when Ss were required to make "same-different" judgments, their responses were faster when only the physical properties of the stimuli had to be examined in order to make a judgment. All these studies suggest that material introduced into the system is handled in a hierarchical fashion with physical or immediate sensory features being analyzed first.

Shulman (1969) has proposed that the encoding of an item takes place over time. In line with the concept of hierarchical analysis of input material, he has suggested that the features most closely related to the sensory input are encoded more rapidly than are the other features. If S is required to recall values from moving pointer and moving scale displays, then in order to maximize the time available for rehearsal, and under the pressure of a brief exposure duration, he attempts to encode the information as quickly as possible. This implies that encoding will begin with the sensory attributes of the input, i.e., with the moving pointer display, S will first encode the pointer position information.

Thus, it is suggested that with the moving pointer display, S first encodes pointer position information. Whatever time remains may be devoted

to verbal encoding of the display reading. It is, of course possible, that these encodings are started simultaneously, although the former, being more closely related to the sensory input, is completed sooner. In contrast, the moving scale display offers no similar position information and only verbal encoding is involved. Elkins' (1959) data on qualitative reading of different displays lend support to this conception of how S is processing information. His finding that reading performance with the moving pointer display was superior to that with the moving scale display may be explained by assuming that merely from pointer position S may obtain all the information required for accurate qualitative reading. Thus with a brief exposure duration he is able to rely on such information which may be obtained more rapidly than the verbal information which he must extract in order to make a qualitative reading from the moving scale displays. Thus, if recall for readings from these two displays is compared, it would be expected that while precise accuracy might not differ between the moving pointer and moving scale displays, the errors with the former should be smaller than those with the latter since recall of the pointer position roughly indicates the correct value.

Three types of display were selected for study, a moving pointer, a moving scale, and a digital counter. Experiment I was designed to provide some baseline data on reading performance for two of the three selected displays. Experiment II attempted to answer the question about the memory differences between the displays. Experiments III and IV were designed to shed light on a theoretical issue that arose from the results of Experiment II.

CHAPTER II

APPARATUS AND STIMULUS MATERIALS

During the entire research program the same basic apparatus was used. The Ss were seated in a dimly lit soundproof booth facing a glass window in front of a screen on which the stimuli appeared; Ss were approximately 106 cm from the screen. The stimuli were on slides which were back-projected onto the screen via a simple mirror arrangement by a system consisting of two Kodak Carousel Projectors controlled by an electronic sequence timer. The timer was programmed to permit a set of slides to be projected in a determined sequential order for the various required exposure durations. A two-way intercom system permitted communication between S and E.

A single set of stimulus materials was used throughout the series of experiments although not all stimulus types were used in each experiment. The stimuli were 2 x 2 black-on-white slides, consisting of pictures of quantitative displays set at various values. Three different kinds of displays were selected for study, a moving scale, a moving pointer, and a digital counter as illustrated in Figure 1. On the moving scale display the pointer remained fixed while the scale moved past the open window; two numbers were always visible and the numbers increased from left to right. On the moving pointer display the scale was fixed while the pointer moved around the dial face. Display readings were always whole numbers. Both the moving pointer and the moving scale displays had a scale range of 200, extending from 100 to 300, a numbered interval value of 10 (major graduation marks) and

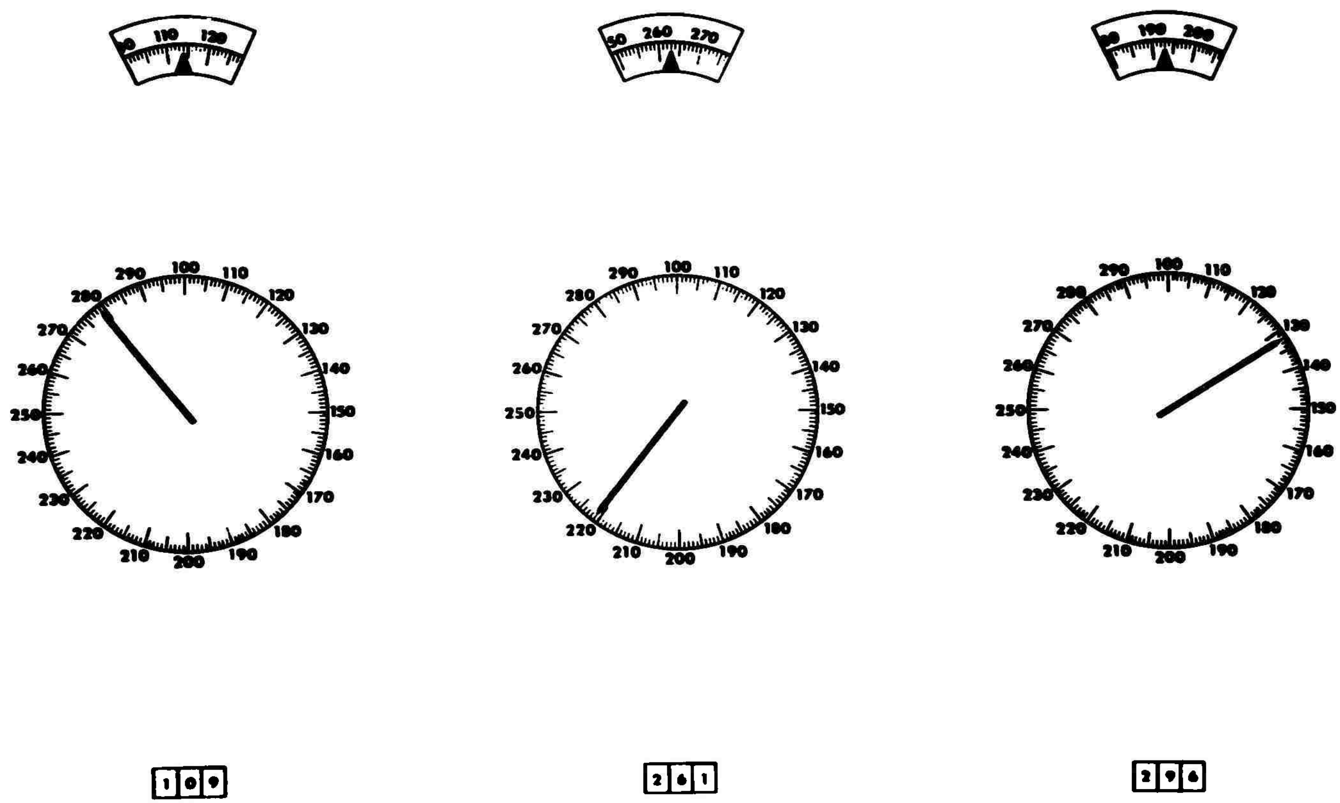


Fig. 1. Examples of the displays used as stimuli.

a graduation interval of 1 (minor graduation marks), with intermediate graduation marks every 5 units. The dimensions and spacing of the markings were identical for both displays. When the displays were projected in the apparatus the lengths of the major, intermediate and minor graduation marks were 0.7 cm, 0.5 cm, and 0.25 cm respectively, while the corresponding widths were 0.075 cm, 0.05 cm, and 0.033 cm. The third display was a digital counter having a scale range of 200, from 100 to 300. Tactype Future Demi Numerials were used whose dimensions were identical for all three displays and when projected their height and width were 0.4 cm and 0.2 - 0.3 cm respectively. All three displays were designed in accordance with recommended specifications (McCormick, 1964).

When projected in the apparatus the visual angles subtended by the largest dimensions of the digital counter, moving scale and moving ponter were 1° 24', 2° 40', and 5° 52' respectively. The brightness of the background of the stimuli measured by a Macbeth Illuminometer was 20 ft Lamberts.

CHAPTER III

EXPERIMENT I

Introduction

While the data of Sleight (1948), Christensen (1952) and Elkin (1959) among others point to differences in the efficiency with which various dials can be read, not all of the data agree. Both Sleight and Elkin demonstrated that reading performance using a moving scale dial was better than using a moving pointer dial. Although Christensen obtained this ordering at short exposure durations, he found that when the exposure duration was increased above 600 msec. this ordering was reversed. Some of these differences may be due to the reading task complexity, scale and marking differences or to the particular exemplar of moving pointer or moving scale that was used. For this reason it was considered important to obtain baseline reading data with the displays that would be used for further information processing experiments, rather than rely on the data obtained by other experimenters. In this experiment an attempt was made to obtain such data on reading performance for two of the three different displays which had been selected for study; the circular moving pointer dial and the open window moving scale dial.

Method

Subjects.--The Ss were six male and six female paid volunteers having 20/20 vision either corrected or uncorrected. All were students at the University of Michigan.

Apparatus.--The apparatus that was used has been fully described in Chapter II.

Stimulus materials.--The stimulus materials have been fully described in Chapter II. Only the moving pointer and moving scale dials were used since pilot data with the digital counter indicated perfect reading performance in the range of exposure durations tested in this experiment.

Experimental design.--Two dial faces were used, the moving scale and the moving pointer and Ss were required to read aloud the three digit number corresponding to the dial setting at three different exposure durations; 0.75, 1.00, and 1.25 sec. Thus a 2 x 3 within-subjects design was employed. Different dials and exposure durations were blocked making six blocks of trials per S. Three different stimulus sets each consisting of random orderings of 34 different dial readings were combined with the three exposure durations in a Graeco-Latin Square design, half the Ss reading the moving scale first and half reading the moving pointer first. Each block consisted of one type of dial exposed for one of the three exposure durations. The order of the 34 dial readings within a stimulus set remained the same throughout the experiment. The particular readings used in each set were chosen so that, as near as possible, the nine final digits 1 - 9 (0 was omitted), the ten middle digits 0 - 9, and the first two digits were equally represented.

Procedure.--The Ss were told that the purpose of the experiment was to study the ease and accuracy with which one can read a dial face that is exposed for varying lengths of time. They were instructed to read the dial as accurately as possible; they were paid 1/2¢ for each correct

reading that they made and they lost 1/2¢ for each error. The trials were blocked as described above and S rested briefly between blocks. In each block the first 8 presentations were regarded as practice trials followed by 26 scored trials. At the start of each trial a row of asterisks appeared on the screen for 1 sec. This acted as a warning that a picture of the dial would follow very shortly and it also served as a fixation line for S as the dial appeared in about the same position on the screen. The dial stayed on the screen for a fixed duration which remained constant throughout the block, but varied from block to block. After the dial appeared S's task was to read aloud the three digit number represented on the dial face. There was about 8 sec. in which to do this and relax before a row of asterisks once again appeared signalling the start of a new trial. Ss were required to make a response on each trial even if they had to guess one or more of the three digits. E heard S read off the three digit number through the intercom system and recorded this number on the score sheet. S received feedback as to the number of errors made at the end of each eight practice trials and at the end of each block.

Results

The Ss' readings were compared with the actual dial readings and the percentage error for each dial at each exposure duration was calculated. Figure 2 shows the percent reading error for each dial as a function of exposure duration. A three-way within-subjects analysis of variance was performed with the square-root transformation of the number of errors as the dependent variable. A transformation had to be applied to the

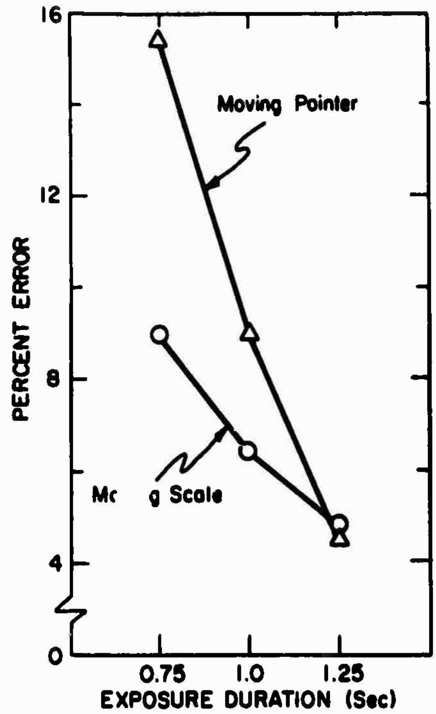


Fig. 2. Percent reading error as a function of exposure duration with type of display as the parameter.

raw error scores in order not to violate the assumptions of the analysis of variance, since the cell means and cell variances tended to be positively correlated. Since the within-cell distribution was Poisson in form, and the number of errors was small, a form of the square root transformation was selected;

$$X' = \sqrt{X + 1/2} \ .$$

A significant main effect due to exposure duration [$F(2,22) = 11.25$, $p < 0.01$] was obtained. There was also an effect due to dial face [$F(1,11) = 4.63$, $p < 0.01$]. Figure 2 shows that performance with the moving pointer dial was inferior to that with the moving scale dial at 0.75 and 1.00 sec exposure durations while performance with the two dials at 1.25 sec was essentially the same. A significant interaction between dial face and exposure duration was not obtained despite a trend in that direction.

Discussion

The main finding of this experiment, that at short exposure durations reading performance with a moving scale dial was superior to that with a moving pointer dial, confirms the results of some previous experimenters (Sleight, 1948; Elkin, 1959) who obtained similar rankings. The data suggest that more processing was required to read and interpret the moving pointer dial than to do so with the moving scale dial. It should also be mentioned that performance of the six male Ss was generally superior and less variable than that of the female Ss, and for this reason only males were run in subsequent experiments. The present results provided data that may serve as comparison data for future results. It also contributed to a judicious choice of exposure duration for subsequent experiments.

CHAPTER IV

EXPERIMENT II

Introduction

This experiment was designed to examine the proposition that quantitative information from one kind of display is better retained in short-term memory than the same information which has been read off another kind of display. Experiment I established differences in the ease with which Ss read two of the three particular displays chosen for study, and it was considered possible that comparable differences might exist in memory for the readings. In a real-life situation an operator may read a display and be required to retain the information for some period before using it. This period during which he retains the information is unlikely to be one in which the operator is idle; more likely he will be intensely occupied.

The Brown-Peterson paradigm to study short-term memory simulates this situation in the laboratory (Brown, 1958; Peterson and Peterson, 1959). The S is presented with a "to-be-remembered item" and the time period between the item's presentation and its recall is filled with another activity that may be related or unrelated to the material held in store. This is the paradigm which was used in the present experiment to study differences in short-term memory for quantitative information from various visual displays.

Method

Subjects.--The Ss were 24 male paid volunteers between the ages 18-25 years all having 20/20 vision either corrected or uncorrected.

Apparatus.--The same apparatus was used as in Experiment I.

Stimulus materials.--The three types of displays described in Chapter II were used; the moving scale, the moving pointer, and the digital counter. The readings displayed were always whole numbers not involving interpolation between minor markers.

Experimental design.--The experiment was divided into three parts, the first and final parts consisting of reading trials similar to those in Experiment I except that a constant stimulus exposure duration of 1.5 sec was used. In both parts S received three blocks of trials, one for each display type. In Part I there were 34 trials per block, the first 8 of which served as warm-up trials followed by 26 scored trials. In Part III there were 10 trials per block with no warm-up trials. In both parts S was required to verbally report the three digit reading represented on the display. The order of presentation of blocks was counterbalanced over Ss and at the end of each block E told S how many errors he had made on that block. The trials in Parts I and III provided an estimate of reading accuracy at a stimulus exposure duration of 1.5 sec.

Short-term memory for readings from the different displays was examined in Part II using a Brown-Peterson paradigm with varied retention intervals. After a warning signal, a picture of the display was projected on the screen for 1.5 sec during which time S was instructed to read to himself the three digit number represented on the display. Immediately after the display disappeared a letter of the alphabet appeared for 0.5 sec. S was then required to recite the alphabet backwards during

the retention interval starting with the presented letter and continuing until a row of asterisks was displayed at which time S attempted to recall the reading. A different display type was represented in each main block which consisted of 30 trials. Each S was tested with each display 10 times at each of the 3 retention intervals, 5, 10, and 20 sec. A specific retention interval was represented once in each successive block of three presentations, the order of the intervals within such blocks being randomized, but in such a way that the first order transitional properties of the retention intervals were as equal as possible. The first two presentations in each main block were considered practice trials and S was so informed. The following four trials were present in order to stabilize proactive interference, which typically, in this paradigm, builds up over the first four trials and then levels off (Keppel and Underwood, 1962); these trials were not scored. The remaining 24 trials, 8 at each retention interval, were scored.

Procedure.--The instructions to Ss for the first and third parts of the experiment were essentially the same as in Experiment I; they were urged to be as accurate as possible. In the second part Ss were told that the purpose of the experiment was to study how well they could remember readings from different displays when doing something else. They were given extra pay for each correct recall they made, but they were instructed to recite the alphabet backwards as fast and as accurately as possible and were so encouraged from time to time during the block of trials. See Appendix I for detailed instructions. They were instructed to guess all or part of the number if they could not

remember it. On each trial the word "ready" presented for 1 sec warned S that a picture of the display would follow very shortly. The display was presented for 1.5 sec and S read off to himself the three digit number, performed the interpolated activity and subsequently attempted to recall the number. There was a ten second period allowed for recall and relaxation between trials. S rested briefly between blocks and also between parts of the experiment. E monitored S's performance on the interpolated activity via the speaker system and recorded recall responses.

Results

For the first and third parts of the experiment the percent reading error for each display was obtained. Table 1 shows these data. As

TABLE 1

PERCENT READING ERRORS ON DIFFERENT DISPLAYS AT 1.5 SEC EXPOSURE DURATION

	Part 1: 26 Trials Per S		
	Dial Type		
	Moving Scale	Moving Pointer	Digital Counter
% Error	3.7	6.4	0.0
	Part 3: 10 Trials Per S		
	Dial Type		
	Moving Scale	Moving Pointer	Digital Counter
% Error	4.2	5.4	0.0

expected Ss made no reading errors with the digital counter; performance with the moving scale display was superior to that with the moving pointer display.

These results confirm the findings of Experiment I in which the same relative ordering was obtained. However, it should be noted that reading the displays in Parts I and III may well be different from reading the displays in Part II in which S knew that he would subsequently be required to recall the number. This expectation possibly may have influenced reading performance (cf., Triggs, 1968).

In the second part of the experiment S's recall responses were scored against the actual readings from the display and the percent recall for each display at each retention interval was calculated. Figure 3 shows the percent recall for each display as a function of retention interval.

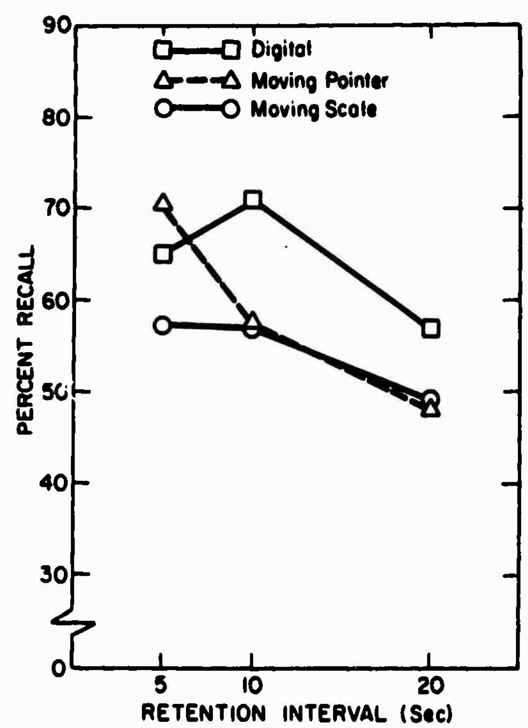


Fig. 3. Percent recall of the display reading as a function of retention interval with display type as the parameter.

Despite the low point at the 5 sec retention interval for recall of the digital counter readings, performance with this display appears to be superior to that with the other two displays. On these, performance was about equal except at the 5 sec retention interval at which the moving pointer recall was superior.

In addition to the recall responses being scored correct or incorrect, the size of the errors was also scored. Thus, if the correct reading was 186 and S's recall was 193, this was scored as an error of +7 units. The errors were then classified in one of five ways according to the following scheme.

i) The three recalled digits were the same as those displayed but the order was incorrect, i.e., a reversal error. This was designated V_1, e.g., 286 recalled instead of 268.

ii) Only the first digit was incorrect. This was designated V_2, e.g., 173 recalled instead of 273. It should be noted that all readings fell between 100 and 299.

iii) The first two digits were correct but the final digit was incorrect. This was designated S, a small error, e.g., 143 recalled instead of 147. Most of the reading errors fell into this category.

iv) The first two digits were not correct but the size of the error was $<$ 25 units. This was designated M, a medium error, e.g., 153 recalled instead of 147.

v) The size of the error was $>$ 25 units. This was designated L, a large error, e.g., 213 recalled instead of 156.

All errors were examined first as to whether they belonged to categories V_1 or V_2. If they did not they were then placed in category S, M, or L. Thus 241 recalled instead of 214 was classified V_1 while 242 instead of 214 was classified L. Table 2 shows the number of errors so classified for the moving pointer and moving scale.

TABLE 2

ERROR CLASSIFICATION FOR EXPERIMENT II

	Retention Interval (sec)					
	5		10		20	
	MS	MP	MS	MP	MS	MP
V	0	3	0	1	0	1
V	10	2	12	2	8	0
S	29	29	32	36	30	43
M	12	18	16	25	19	32
L	31	4	23	18	41	23

The data for the digital counter have been omitted here because it was felt that this display presented very different task demands in terms of reading the number than did the other displays. The comparable data for this and subsequent experiments are reported in Appendix II. Reading the moving pointer display required location of the pointer and interpolation between two numbered markers. Reading the moving scale display required merely the interpolation. In this and subsequent experiments only the moving pointer and the moving scale will be compared when considering the nature of the errors. Figure 4 shows the number of M and L errors for the moving pointer and moving scale displays at different retention intervals.

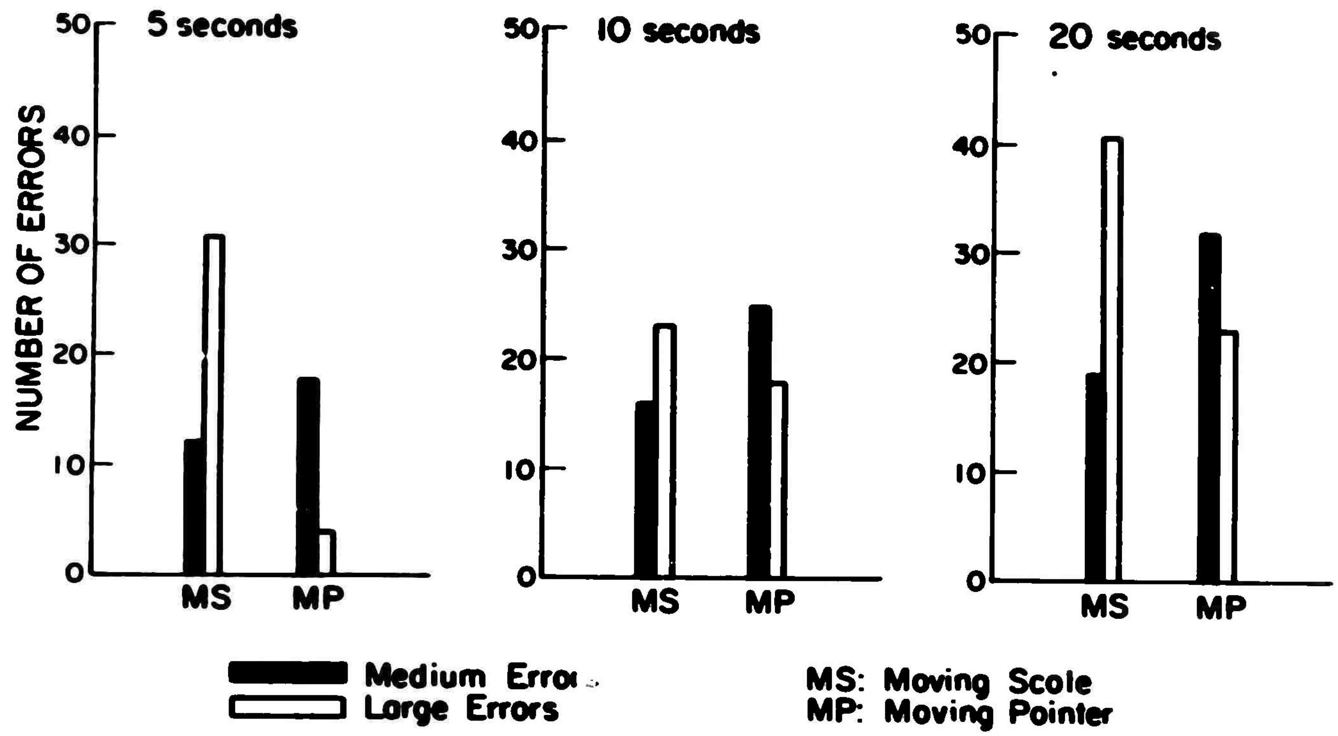


Fig. 4. The numbers of medium and large errors made with the moving pointer and moving scale display at each retention interval.

A composite score of $\frac{M + 1/2}{M + L + 1}$ was calculated for each S under each condition. This score reflects the number of M errors as a proportion of the total number of M and L errors. The 1/2 added to both M and L avoids the problem of having a zero score in the numerator or denominator. When the entries in both the M and the L category are zero the composite score is 0.5. As the number of errors in the M category increases the composite score tends to 1 while as the number of errors in the L category increases the score tends to 0. Table 3 shows the mean $\frac{M + 1/2}{M + L + 1}$ ratios.

TABLE 3

MEAN $\frac{M + 1/2}{M + L + 1}$ RATIOS FOR EXPERIMENT II

Retention Intervals (sec)					
5		10		20	
MS	MP	MS	MP	MS	MP
0.41	0.61	0.45	0.53	0.41	0.55

A three-way within-subjects analysis of variance was performed with the $\frac{M + 1/2}{M + L + 1}$ ratio as the dependent variable. A significant main effect [$F(1,23) = 17.25$, $p < 0.01$] due to display type was obtained, but no other significant main effects or interactions were obtained.

Discussion

There appear to be differences in short-term memory for readings from the three kinds of displays. Recall from the digital counter was

superior to that from the other displays on which performance was approximately equal. Caution, however, should be taken in interpreting these results since reading has been shown to be less accurate for the moving pointer than for the moving scale display. Since Ss were not required to read aloud the three digit number in the second part of the experiment, there is no way to extricate reading errors from memory errors. The results of Parts 1 and 3 provide an estimate of reading accuracy, but as mentioned, differences might exist between the reading tasks in those parts and in Part 2 of the experiment.

With respect to the memory differences between the displays it is interesting that the digital counter, which is the easiest to read, resulted in the best recall. This result weighs against any hypothesis that suggests that the more effort required to perform a task, in this case reading the display, the better the recall associated with that task. A more feasible explanation of the superiority of performance with the digital counter is that Ss were able to read the display and rehearse the reading within the alloted 1.5 sec, while with the other two displays, they needed the entire time just to read the number.

Of greater interest, however, are the differences in the size of errors obtained on the moving pointer and moving scale displays. From Table 2 it is clear that Ss made more V_2 errors with the moving scale than with the moving pointer. These are errors in which only the first digit was incorrect. If the pointer on the moving pointer display is on the left-hand side of the display, the reading must be in the two hundreds, and in the one hundreds if the pointer is on the right-hand side. No

such positional information is available with the moving scale display. If Ss were able to retain even the crudest position information with the moving pointer display, they would be less likely to make an error on the first digit. The data suggest that this indeed happened. However, more pertinent to the question of spatial information, are the numbers of medium and large errors. Suppose, that with the moving pointer S tries to remember the approximate position of the pointer as well as the exact reading on the display. If S forgets the reading but is still able to retrieve some pointer position information, then his error should be smaller than if he had no such information. The class S of small errors probably results from: a) Reading errors, where the number read is correctly recalled and b) Errors where verbal recall is almost perfect and only the last digit is missed. The class M of medium errors probably contains few reading errors, but consists of those errors where more of the verbal memory has been lost and the middle or "tens" digit is incorrect. The class L, of large errors is primarily composed of errors where verbal recall is poor. Naturally there were occasions on which S when having neither verbal nor spatial information guessed the number and his response was either correct or fell into categories S or M. When there is no memory for spatial information available, there is no reason to expect that for any of the displays, these guesses should fall more often into one category than into another. However, it has been suggested that there is spatial or positional information present in the moving pointer display but not in the moving scale display, and support for this is forthcoming from the number of V_2 errors made with the two different displays. If indeed spatial information is available, then

it might be expected that when S has imperfect verbal memory of the three digit number he is able to utilize the information in his spatial memory to make a more accurate recall attempt. If Ss were able to retain spatial information, such as in which quadrant of the display the pointer was located, then when verbal memory for the number was imperfect, and they guessed using the spatial information, their error should be ± 25 units, i.e., in the M category. Figure 4 shows quite clearly that more M errors were obtained under the moving pointer than under the moving scale conditions and the difference in this respect was confirmed by the significant main effect in the analysis of variance.

This experiment has demonstrated that there are differences in short-term memory for readings from among the various displays. Although in a real world situation a person would be unlikely to read aloud from a display, care must be taken in the interpretation of these differences due to the fact that reading and memory errors were partially confounded, since there was no way to ascertain whether S had correctly read the display. The hypothesis that there is spatial information present in the moving pointer display which S can attempt to remember, received support from the analysis of the error data.

While this experiment did not attempt to evaluate check-reading performance, it certainly provides some pertinent information. There is a large element of memory involved in check-reading as the operator periodically views the display to ascertain whether the indicated values are normal or have changed. Here he must remember the previous value in order to make a comparison. Precision of the type demanded in the present study

is not usually required; more often just a rough estimate is sufficient. It has been demonstrated that pointer position can be encoded and retained in short-term memory. This then suggests that for check-reading, moving pointer displays would result in the best performance since the pointer position can be ascertained rapidly and recalled adequately.

Experiment III was designed to follow up some of the theoretical points that had been raised by the results of this experiment and also to try and separate reading and memory errors which were confounded in this experiment.

CHAPTER V

EXPERIMENT III

Introduction

In the Brown-Peterson paradigm the interpolated activity serves to occupy S's capacity so that little if any is available for rehearsal of the "to-be-remembered item." The interpolated activity also provides a source of retroactive interference. Thus one might expect that in this experiment an interpolated task requiring the use of numbers, e.g., counting backwards by three's, would result in inferior recall from all displays, than that obtained with the interpolated task of reciting the alphabet backwards. The numbers that would be processed in the course of performing the interpolated activity would retroactively interfere with memory for the number read off the display. In general, the more similar the interpolated activity is to the material which must be remembered, the more interference (Brown, 1958; Corman and Wickens, 1968; Dale and Gregory, 1966).

In Experiment II some evidence was found for the use of spatial information and this suggested that spatial short-term memory was involved. There is experimental evidence for the existence of spatial as well as verbal short-term memory (Brooks, 1968; Margrain, 1967) and some of the work on visual search suggests that the stimulus representation might be a pictorial one (Sternberg, 1969). In Experiment II it is reasonable to suppose that the interpolated activity of reciting the alphabet backwards interfered equally with the verbal memory from all displays. However,

it did not interfere to the same degree with spatial memory. In order to more explicitly demonstrate the usefulness of spatial information in connection with the moving pointer display, an interpolated task was designed which it was hoped would interfere selectively with spatial memory. The chosen task was a modification of one used by Brooks which he had shown to involve spatial processing. This experiment was designed to provide an explicit demonstration of spatial information by comparing performance under the present interpolated task with performance under a task which would provide spatial interference. It was also intended to provide explicit data on the relation between reading and memory errors.

Method

Subjects.--The Ss were 36 male paid volunteers between the ages 18-25 years all having 20-20 vision either corrected or uncorrected.

Apparatus.--The same apparatus was used as in Experiment I.

Stimulus materials.--The same stimulus materials were used as in Experiment II.

Experimental design.--The Brown-Peterson paradigm was employed in a between-subjects design in which there were two groups of Ss. For one group of 18 Ss the interpolated task was reciting the alphabet backwards (non-spatial group) and for the other group of 18 Ss it was a task designed to produce spatial interference (spatial group). In the spatial task a block letter of the alphabet in outline was projected on the screen. In one corner of the letter there was a black dot together with an arrow pointing in the direction of an adjacent side of the letter (see Figure 5).

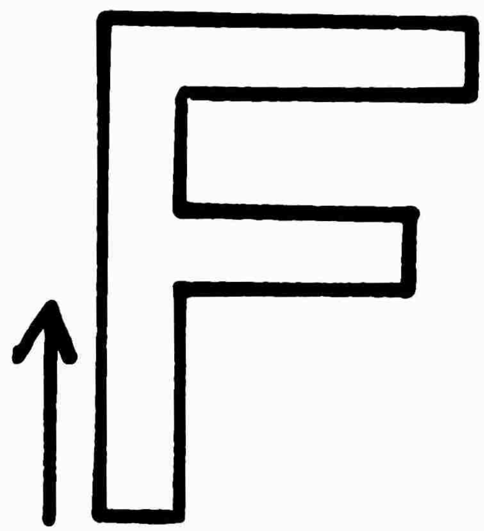


Fig. 5. A sample of the outline letters used.

Ss were required to start at the spot and proceding in the direction of the arrow trace out the letter going from corner to corner by using the directions of the compass. They were instructed to use eight compass directions N, S, E, W, NE, NW, SE, and SW, and to assume that any diagonal was along the 45° mark, i.e., NW, NE, SW, or SE. When they arrived at the starting corner they imagined the letter rotated 90° clockwise about that point and once again traced out the figure. They continued the sequence of tracing, rotating, tracing, etc. until the end of the retention interval.

The experimental design was similar to that in Experiment II. S received 3 blocks of 10 trials each for reading practice, one block for each display type. The order of the blocks was counterbalanced over Ss. Following these reading blocks there were 3 memory blocks, one for each display which were similar to those in Experiment II. Again a Graeco-Latin Square design was used.

Procedure.--The instructions to the subjects were similar to those used in the previous experiment except that Ss were not paid extra for each correct recall but were paid double the base rate for performing well on the interpolated activity. At the start of each trial the word "ready" was projected on the screen for 1 sec. This warned the Ss that a picture of the display would follow almost immediately and it also provided them with a fixation mark. The picture of the display was exposed for 1.5 sec during which time S read aloud the reading represented on the display. Immediately after the display disappeared an outline letter of the alphabet appeared. S performed the appropriate interpolated task according to which group he had been assigned. For the non-spatial group the letter was exposed for 2 sec and then followed by the retention interval. For the spatial group the letter remained throughout the retention interval, i.e., 2 sec plus the interval. A row of asterisks signalled the end of the retention interval at which time S had 10 sec in which to recall the display reading and relax before the start of a new trial. Ss were instructed to guess if necessary. E recorded the recall responses. Ss rested briefly between the various blocks of trials.

Results

The data were analyzed in the same fashion as in the previous experiment except that the reading which S made was taken as the correct reading, and he was scored correct in recall only if his recall corresponded to his reading. In this way the retention curves were not contaminated with

reading errors. The reading errors on the recall trials were scored and Table 4 shows the percentage of reading errors for both groups. There

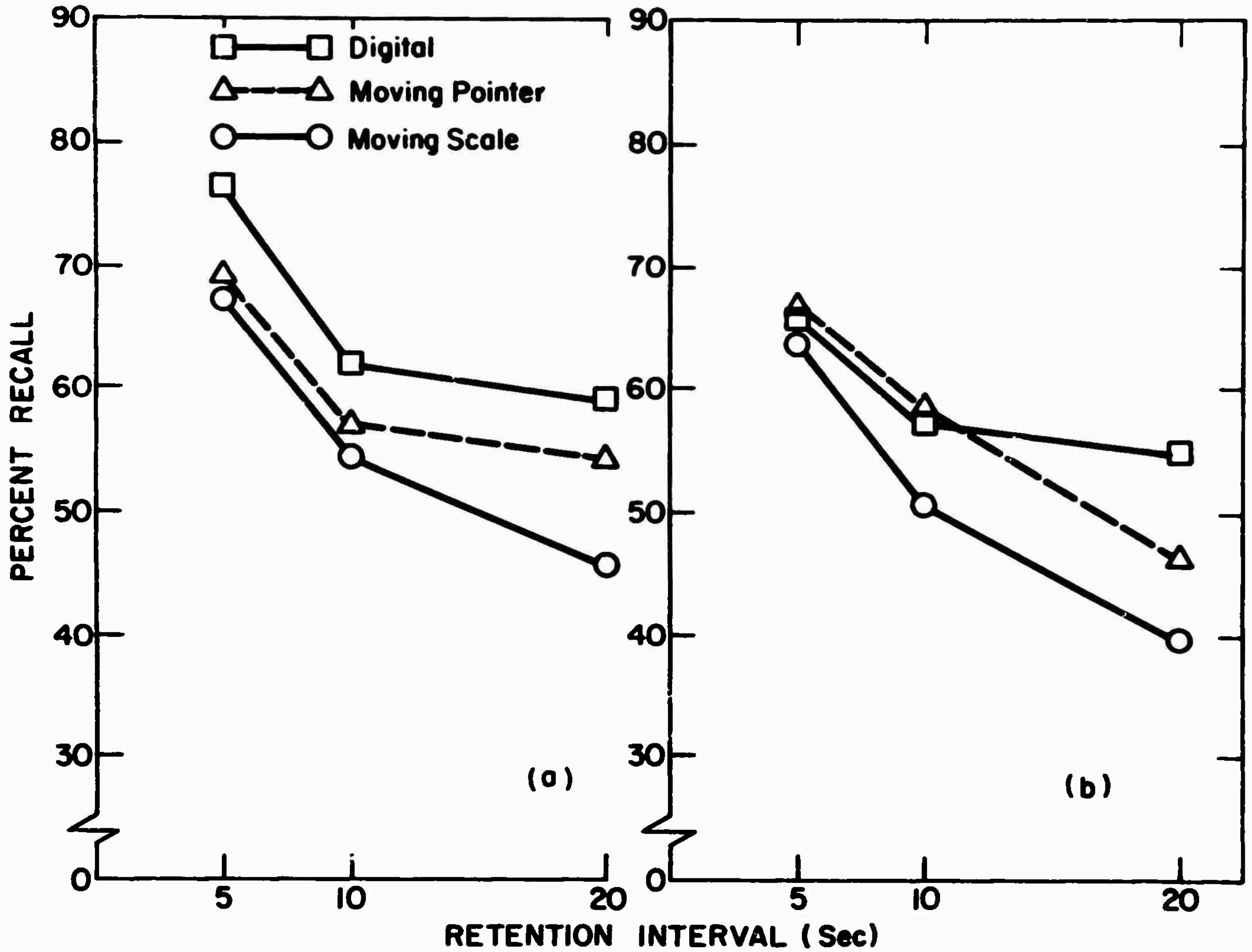
TABLE 4

PERCENT READING ERRORS FOR BOTH GROUPS IN EXPERIMENT III

	Display Type		
	Moving Scale	Moving Pointer	Digital Counter
Spatial Group	5.09	8.56	0.0
Non-Spatial Group	8.33	8.33	0.0

is a slight increase in errors when S knows that he must subsequently recall the reading and this emphasizes the caution which should be maintained in interpreting the results from Experiment II. Figure 6a shows the percent correct recall for each display as a function of retention interval for the spatial group. Figure 6b shows the same function for the non-spatial group. Recall performance was best with the digital counter followed by the moving pointer and the moving scale in that order. The overall recall performance of the spatial group was superior to that of the non-spatial group.

The classification of errors on the moving pointer and moving scale displays for both groups is presented in Table 5. The differences between the displays on the M and L errors that were demonstrated in Experiment II are no longer present for the spatial group. Although they are present for the non-spatial group, the effect is weak. An analysis of variance was performed on the data with the $\frac{M + 1/2}{M + L + 1}$ ratio as the dependent variable. The only significant term was the main effect due to retention



Figs. 6a and 6b. Percent correct recall as a function of retention interval with display type as parameter.

Fig. 6a. Spatial interpolated task. Fig. 6b. Non-spatial interpolated task.

TABLE 5

ERROR CLASSIFICATION FOR EXPERIMENT III

Spatial Interpolated Task

Retention Interval (sec)

	5		10		20	
	MS	MP	MS	MP	MS	MP
V_1	0	0	2	3	0	0
V_2	4	4	5	4	10	3
S	16	8	21	11	14	11
M	9	11	15	19	11	15
L	18	21	23	25	43	37

Non-Spatial Interpolated Task

Retention Interval (sec)

	5		10		20	
	MS	MP	MS	MP	MS	MP
V_1	0	0	1	0	0	0
V_2	8	6	10	3	8	5
S	5	19	14	23	15	25
M	17	10	16	20	19	23
L	22	13	30	14	45	24

interval [$F(2,68) = 3.46$, $p < 0.05$]. Table 6 shows the mean $\frac{M + 1/2}{M + L + 1}$ ratios for each group for the various conditions. Here again in the non-spatial group, the effect is present but very weak. Figure 7 shows the number of M and L errors for the moving pointer and moving scale displays for the two groups.

TABLE 6

MEAN $\frac{M + 1/2}{M + L + 1}$ RATIOS FOR EXPERIMENT III

Spatial Group

Retention Interval (sec)

5		10		20	
MS	MP	MS	MP	MS	MP
0.44	0.47	0.48	0.49	0.32	0.42

Non-Spatial Group

Retention Interval (sec)

5		10		20	
MS	MP	MS	MP	MS	MP
0.51	0.49	0.42	0.54	0.36	0.52

Discussion

A clearer picture of recall performance was obtained by avoiding the confounding between reading and memory errors. Recall was clearly best with the digital counter and this appears to be a stable finding. From

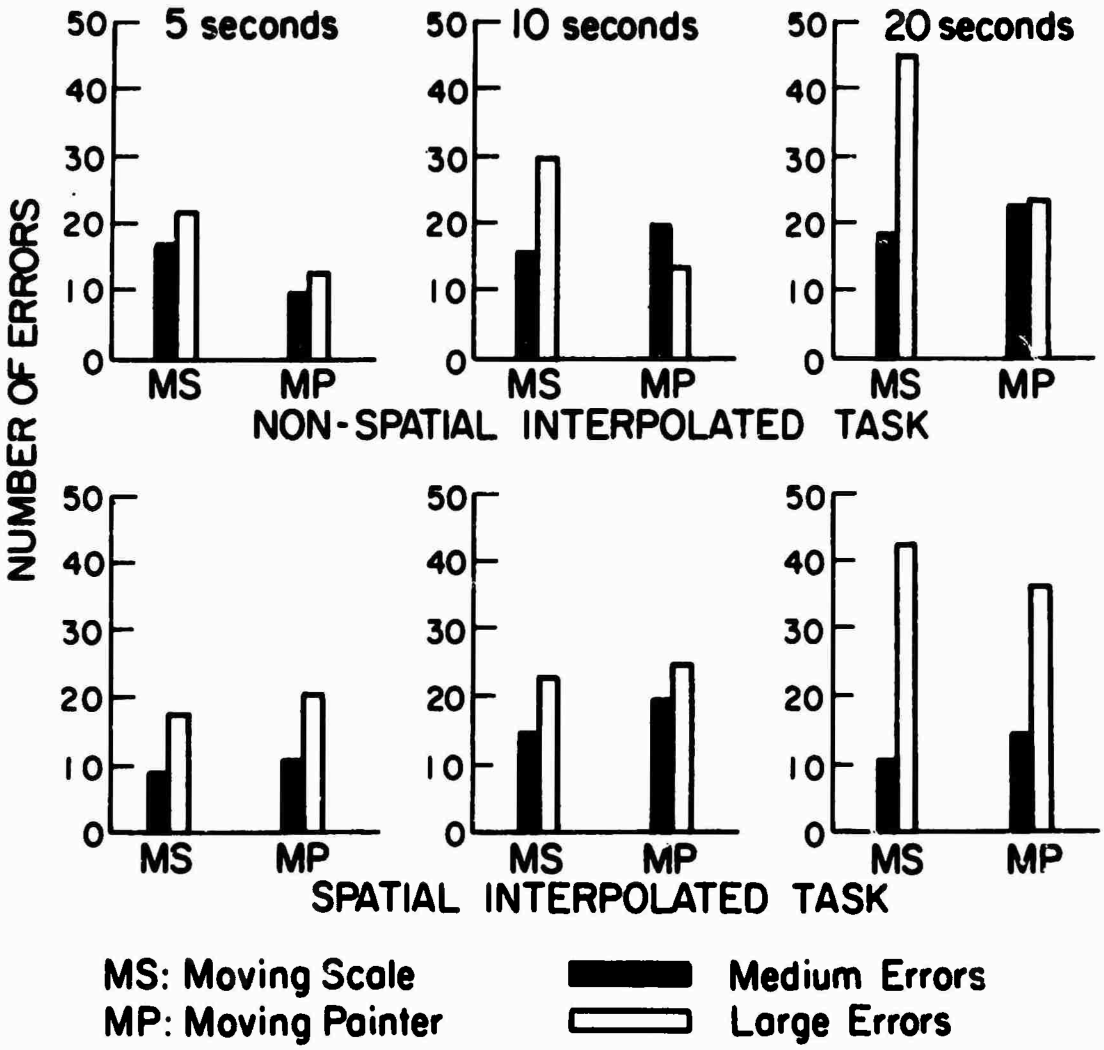


Fig. 7. The numbers of medium and large errors with the moving pointer and moving scale display at each of the three retention intervals under both interpolated task conditions.

Experiment I and the results of other researchers it is known that the digital counter may be read faster and with greater accuracy than either the moving pointer or the moving scale displays. A possible explanation of the superiority in recall of readings from the digital counter is that Ss read off the number so quickly, that before commencement of the interpolated

activity there was time available in which they were able to rehearse the reading and this resulted in better recall. One method to test this would be to measure response and reading times for the various displays and then use these times as the exposure durations in a Brown-Peterson paradigm. If indeed this facility of reading hypothesis is true, then this procedure should abolish the differences in recall performance between the displays. The recall performance difference between the moving pointer and moving scale displays cannot be accounted for by this hypothesis. For both groups recall using the moving pointer display tended to be better than recall using the moving scale display while the reverse ordering was obtained for reading performance. This difference may be due to the presence of spatial information. If S remembered on which side of the display the pointer was located, then he had only to recall from verbal memory the last two digits of the reading. In this way he might be able to augment his performance by using his spatial memory. This recall difference between the two displays was larger for the non-spatial than for the spatial group in which there was spatial interference from the interpolated activity. This provides further support for the hypothesis that spatial information was being utilized in recalling the display reading since interference with spatial memory reduced the difference between the displays.

The error data, although weak, similarly support the spatial memory hypothesis. The interesting question is why the spatial effect in the non-spatial interference group was much weaker than that obtained in Experiment II? Experiment IV was designed to answer this question and to provide further evidence for the spatial memory hypothesis.

CHAPTER VI

EXPERIMENT IV

Introduction

There were two major differences between the procedure in Experiment III and that in Experiment II. Firstly, Ss received much more display reading practice in Experiment II and hence were more familiar with the displays and their distinctive properties. Some Ss even reported that half-way through Experiment III they suddenly realized that they could aid their recall in the moving pointer condition by remembering the position of the pointer on the face of the display. The second difference between the two experiments was that in Experiment III S read aloud the display reading before starting the interpolated activity while in Experiment II he read the number to himself. This procedure in Experiment III served to extricate reading from memory errors but may also have put greater emphasis on verbal encoding than on spatial encoding.

The present experiment used a within-subjects design to partially replicate Experiment II. Two different interpolated activities were used to try and provide further evidence regarding the use of spatial information with the moving pointer display.

Method

Subjects.--The Ss were 12 male paid volunteers between the ages 18-25 years all having 20/20 vision either corrected or uncorrected.

Apparatus.--The apparatus was the same as that used in the previous experiments.

Stimulus materials.--The same stimulus materials were used as in Experiment II.

Experimental design.--A two-part within-subjects design was used; the two parts differed only in using different interpolated tasks. In Part 1 S received three blocks of reading trials, one for each display type; the displays were individually exposed for 1.5 sec. These reading trials were followed by three blocks of trials in a varied retention interval Brown-Peterson paradigm, one block for each type of display. The interpolated task used was reciting the alphabet backwards. The detailed composition and timing of these memory trials was exactly the same as those in Experiment III. The design of Part 2 of this experiment was the same as that of Part 1, consisting of both reading and memory trials; however, the interpolated task was the spatial one of tracing out an alphabet letter, described previously in greater detail. Each S was run first on Part 1 and then on Part 2. All Ss served in all conditions; the same stimulus sets in the same orders were used in both parts. A Graeco-Latin Square was used to counterbalance the order of presentation of blocks over Ss.

Procedure.--The instructions were identical to those used in Experiment II in that accuracy was stressed and Ss were given extra pay for each correct recall. The format of the reading trials was the same as in Experiment II and the format of the recall trials was the same as those in Experiment III. In the recall trials after the word "ready", a picture of the display appeared for 1.5 sec during which time S read the

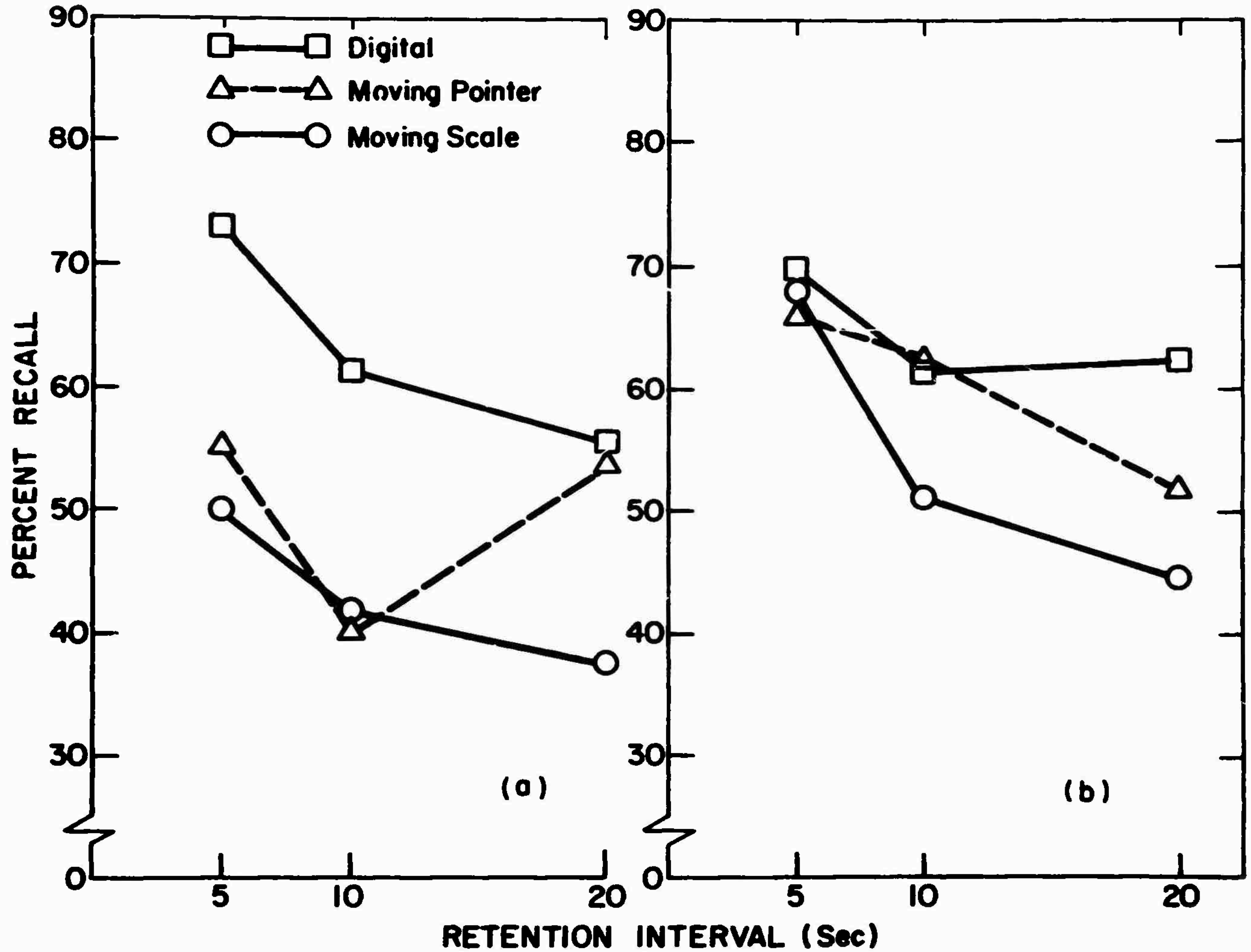
number represented on the display <u>to himself</u>. Immediately after the display disappeared a letter of the alphabet appeared and S began the appropriate interpolated activity. The letter stayed on the screen for either 2 sec (non-spatial task) or throughout the retention interval (spatial task) depending upon which interpolated task S was performing at the time. When the row of asterisks appeared S attempted to recall the reading. E monitored the interpolated activity and recorded recall responses. S rested briefly between blocks of trials.

Results

The data were analyzed in the same way as in Experiment II. Figures 8a and 8b show the percent correct recall for each display as a function of retention interval for the non-spatial and spatial tasks respectively. Here again, as in Experiment II, the recall data were contaminated with reading errors. Despite a couple of errant data points the generally obtained ordering of digital, moving pointer, moving scale appears to hold up reasonably well.

Table 7 shows the classification of errors on the moving pointer and moving scale displays under both interpolated task conditions. The spatial effect obtained in Experiment II where there were many more M errors than L errors on the moving pointer scale is once again evident with the non-spatial interpolated task. This effect has been considerably lessened, if not abolished with the spatial interpolated task.

An analysis of variance performed on the data with the proportion $\frac{M + 1/2}{M + L + 1}$ as the dependent variable yielded significant main effects due



Figs. 8a and 8b. Percent correct recall as a function of retention interval with display type as parameter.

Fig. 8a. Non-spatial interpolated task.

Fig. 8b. Spatial interpolated task.

TABLE 7

ERROR CLASSIFICATION FOR EXPERIMENT IV

Non-Spatial Interpolated Task

Retention Interval (sec)

	5		10		20	
	MS	MP	MS	MP	MS	MP
V	0	0	1	1	0	0
V	6	3	6	1	7	1
S	11	19	18	19	20	17
M	14	14	8	27	6	15
L	17	7	23	9	27	12

Spatial Interpolated Task

Retention Interval (sec)

	5		10		20	
	MS	MP	MS	MP	MS	MP
V	0	0	0	[illegible]	0	1
V	6	2	9	1	6	0
S	10	16	12	12	17	16
M	8	8	8	13	10	10
L	7	6	18	9	20	19

to display type [F = 12.44, df = (1,11), $p < 0.01$] and retention interval [F = 6.74, df = (2,22), $p < 0.01$].

Table 8 shows the mean $\frac{M + 1/2}{M + L + 1}$ ratios for the moving pointer and moving scale displays at different retention intervals with different interpolated activities. While the $\frac{M + 1/2}{M + L + 1}$ ratios for the moving scale increased

TABLE 8

MEAN $\frac{M + 1/2}{M + L + 1}$ RATIOS FOR EXPERIMENT IV

	Retention Intervals (sec)					
	5		10		20	
	MS	MP	MS	MP	MS	MP
Non-Spatial Task	0.46	0.61	0.32	0.67	0.26	0.53
Spatial Task	0.50	0.50	0.38	0.55	0.40	0.39

when S performed recall under the spatial interpolated activity condition, the ratios for the moving pointer decreased. In the analysis of variance the first order interaction Dials x Interpolated tasks was also significant ($F(1,11) = 16.10$, $p < 0.01$). There were no other significant effects.

Figure 9 shows M and L errors for the displays at each retention interval with each interpolated activity. The spatial effect overwhelmingly present with the non-spatial interpolated activity has been virtually abolished by the spatial interpolated activity.

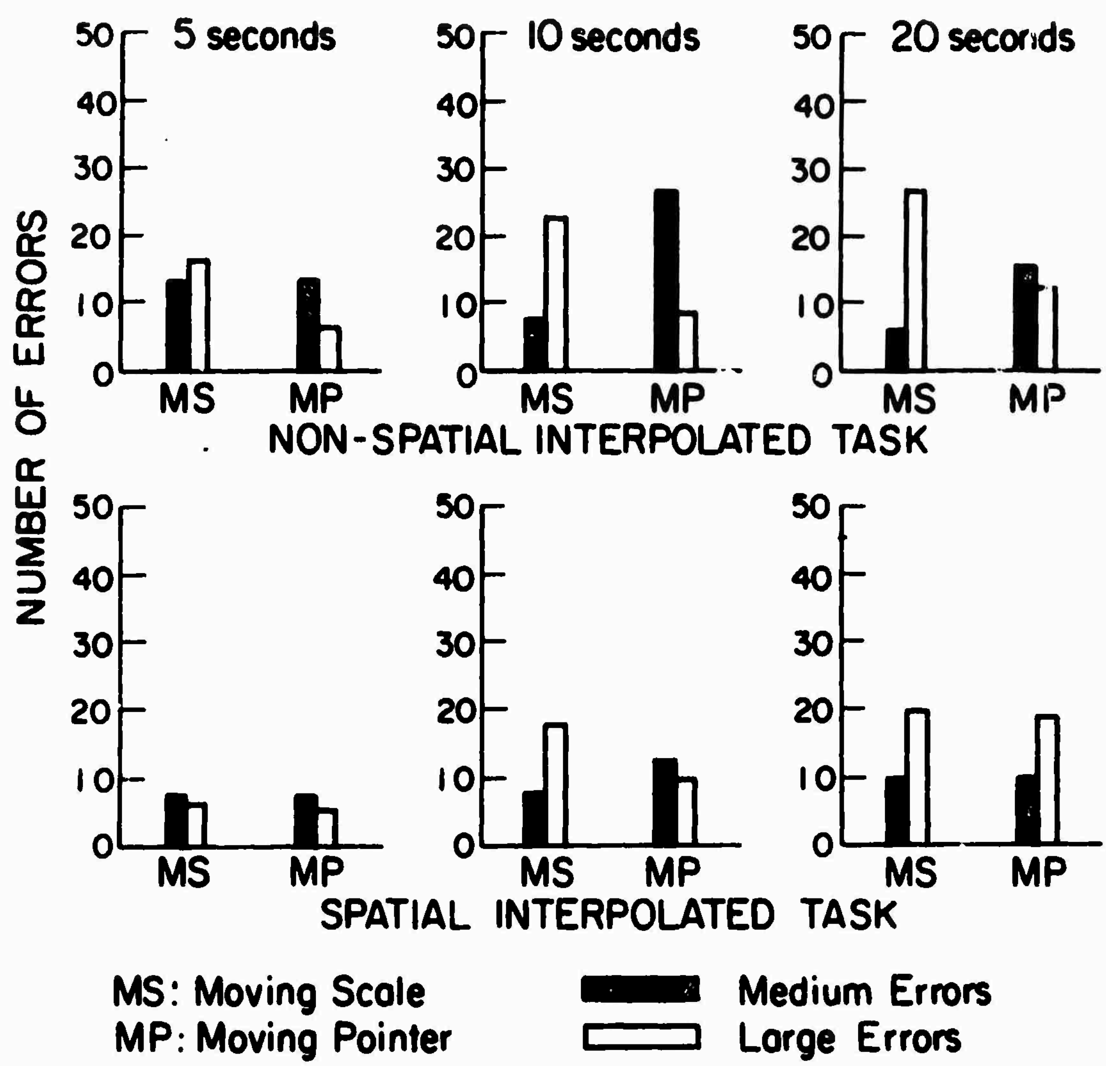


Fig. 9. The numbers of medium and large errors made with the moving pointer and moving scale display at each of the three retention intervals under both interpolated task conditions.

Discussion

The large spatial effect obtained and its subsequent abolition provide substantial support for the hypothesis that with the moving pointer display S is able to use the spatial information from pointer position to facilitate

recall of the display reading. It appears that the spatially interpolated task was less difficult and required less of S's capacity than the non-spatial interpolated task, thereby producing overall superior recall performance. Although superior recall performance by the spatial group was also obtained in Experiment III, it should be noted that the order in which S performed the parts of this experiment was not counterbalanced over S, i.e., all Ss performed first under the non-spatial condition and secondly under the spatial condition. Thus there is a confounding with practice, although it seems unlikely that this seriously affects the conclusions that may be drawn.

In the present experiment improved recall performance tended to result in an increased $\frac{M + 1/2}{M + L + 1}$ ratio. This ratio reflects the magnitude of the errors made. As the errors become mainly large errors, the ratio tends to zero and as the errors become predominately small or medium errors, the ratio tends to one. Examination of Table 8 shows that the ratio increased for the moving scale when S performed first in the non-spatial interpolated task and then in the spatial interpolated task. However, the ratio decreased for the moving pointer from the non-spatial to the spatial task. This decrease together with the increase for the moving scale dial accounts for the significant interaction (Dials x Interpolated task) obtained in the analysis of variance.

Unfortunately the recall data from this and previous experiments was not as clean as hoped and this prevents anything more than speculation about the time course of spatial information. In speculating, it appears that spatial memory decays over time more rapidly than the verbal information.

CHAPTER VII

CONCLUSION

It has been demonstrated that the short-term memory for quantitative information extracted from a visual display is not independent of the type of display from which it comes. In a series of laboratory experiments the obtained ranking of displays in terms of recall performance was digital counter first, followed by the moving pointer and moving scale displays in that order; while the ordering in terms of reading performance was digital counter, followed by moving scale and moving pointer displays in that order. A hypothesis based on facility of reading was proposed to account for the overall superiority of recall for readings from the digital counter. However, this hypothesis does not account for the obtained ordering of the moving pointer and moving scale displays. A second hypothesis invoked the use of spatial information due to pointer position which was present in the moving pointer but not in the moving scale display to account for these differences. It was explained how the use of spatial encoding could augment verbal encoding. Evidence for this hypothesis was obtained by comparing the error patterns resulting from the use of each display. When the interpolated activity between display presentation and recall was of a nature that interfered with only the recall of verbal material, different error patterns for the moving pointer and the moving scale displays were obtained. On the moving pointer idsplay Ss tended to make a larger number of errors whose size was < 25 units than of errors whose size was > 25 units. The reverse

was the case for the moving scale display. When, however, the interpolated activity was one which interfered with recall for spatial as well as verbal material, this difference was either abolished or considerably lessened.

This series of experiments has shed light on two important points. First, that the method by which quantitative information is displayed may affect subsequent human information handling. Second, the nature of the activities between reading a display and subsequent use of the reading appear to determine the recall of such information. Before the result of recall differences between displays may be used practically, a study should be performed that controls for the ease of reading the various displays. In deciding upon which type of display to use for particular kinds of information, the designer should give some consideration then, not only to the ease of reading the display, but also to the factors involving recall of the information read off the display. These factors include: a) How long the information must be retained, b) The purpose for which the information is going to be used, and c) The nature of other ongoing and interpolated activities between reading the display and using the information. While recall was investigated at only three different retention intervals the ordering of digital, moving pointer, and moving scale in descending order of performance, held in general. However, the difference between the moving pointer and the moving scale displays tended to lessen at longer retention intervals and it has already been proposed that memory for non-verbal information might decay more rapidly than that for verbal information, thereby accounting for

that trend. One important factor in any consideration of the subsequent use for the information from a display of the subsequent use for the information from a display is the amount and nature of recall error which can be tolerated. In evaluating a visual display an examination of the nature of errors should always be undertaken. The ordering based on recall performance reports only precise accuracy; it does not say anything about the kind of recall errors that one might expect with a particular display. There are some cases in which large errors have higher negative costs associated with them than do small errors. Although these costs probably lead to more concentration on the part of the operator and therefore better retention, it might be advisable in such a case to consider using some form of moving pointer display so that when an error does occur, it has a good chance of being small. Finally, when recommending the use of one display rather than another one should consider how reading that display fits into the other ongoing activities of the operator. The importance of considering the nature of the activities which follow the reading of the display was demonstrated by the disappearance of error pattern differences between the moving pointer and moving scale displays when the interpolated activity was changed. When the interpolated activity was of a spatial nature, the advantage of the moving pointer was lessened both in terms of precise recall and in the size of errors in the event of forgetting. Naturally in recommending the use of one kind of display rather than another, there are also many other system considerations which should be borne in mind; such things as the length of scale, control motion relationships, etc.

One methodological point worthy of mention is that the differences between the displays in these experiments were obtained under conditions of limited exposure durations. These results might be considerably different if the display exposure durations had been longer or S-terminated. One interesting way in which this problem may be approached would be to use the paradigm developed by Yntema and Trask (1963) in which they investigate S's ability to keep track of the states of several variables. Such a paradigm could be adapted to investigate further the nature of the processing of information from visual displays.

APPENDIX I

INSTRUCTIONS TO SUBJECTS

<u>Experiment I</u>

This is an experiment to study the ease and accuracy with which one can read a dial face which is exposed for varying lengths of time. At the start of each trial you will see a row of asterisks; this is a warning that the dial will follow very shortly. You should fixate this row as the dial will appear in about the same position and this will enable you to read it more accurately. The dial will stay on the screen for a fixed length of time.

There are two different dial faces and we shall test each at three different exposure durations. Thus there will be six blocks of trials in all. The length of time for which the dial face is displayed will remain the same within each block of trials but will change from block to block. After the dial appears your task is to read off the 3-digit number which is on the dial face. You will have about 8 sec in which to do this and relax before a row of asterisks will once again appear signalling the start of a new trial on which a new dial will appear. You should always try and speak the dial reading loudly and clearly so that I can hear you via the two-way speaker system.

The range of all dials is from <u>100-300</u>. Before you read a new kind of dial I shall project a sample of it so that you can familiarize yourself with it. On each block of trials there will be eight practice trials to which you should respond as usual. After these eight we shall start in proper. You will earn extra pay for each correct reading that you make and you will lose credit for each error you make, so please try and be as

accurate as possible. Remember before each trial to fixate the row of asterisks. Please do not move the chair during the experiment; I should like your eyes to remain a constant distance from the screen if possible. Please make a response on each trial even if you have to guess one of the three digits, and always make the best guess possible - this will help your score. If the image is ever fuzzy or out of focus please tell me.

Remember the key thing in this experiment is accuracy. Any questions?

<u>Experiment II</u>

There are three parts to this experiment. I shall read you the instructions to each part separately. After I have read you the instructions for the first part we shall run that part. When you have finished that part I shall read you the instructions for the second part which we shall then run, and finally I shall read you the instructions for the third part and we shall run that.

<u>First part instructions</u>.--This part of the experiment is to study the accuracy with which one can read a dial face which is briefly exposed.

At the start of each trial you will see a row of asterisks; this is a warning that the picture of the dial will follow almost immediately. You should fixate this row as the dial will appear in about the same position and this will enable you to read it more accurately. The dial will stay on the screen for 1.5 sec. After the dial appears your task is to read off the 3-digit number which is on the dial face. You will have about 10 sec in which to do this and relax before a row of asterisks will once again appear signalling the start of a new trial on which a new dial will appear. You should always try and speak the dial reading loudly and clearly so that I can hear you via the two-way speaker system.

There are three different dial faces which we shall test, constituting three blocks of trials. Before you read a new kind of dial I shall project a sample of it so that you can familiarize yourself with it. The range on all dials is from 100-300. On each block of trials there will be eight practice trials to which you should respond as usual. After these eight we shall begin the test series. You will earn extra pay for each correct reading that you make and you will lose credit for each error you make, so please try and be as accurate as possible. Remember before each trial to fixate the row of asterisks. Please do not move the chair during the experiment as I should like your eyes to remain a constant distance from the screen if possible. Please make a response on each trial even if you have to guess one of the three digits, and always make the best guess possible - this will help your score. If the image is ever fuzzy or out of focus at any time during the experiment please tell me and I shall refocus it. Remember the key thing in this experiment is accuracy. Any questions?

Instructions to the second part.--This part of the experiment is to study how well one can remember readings from different dial faces when doing something else.

At the start of each trial you will see the word "ready" projected on the screen; this is a warning that a picture of the dial will follow almost immediately. You should fixate the word "ready" because the dial will appear in about the same position on the screen and this will help you to read it correctly. The dial will stay on the screen for 1.5 sec. Immediately after the dial disappears a letter of the alphabet will appear. Your task then is to begin immediately to recite the alphabet backwards

loudly and clearly, starting with the letter that you see (e.g., If you see the letter H you should say H, G, F, E, etc.). If you come to the beginning of the alphabet you should go to the end and start reciting backwards again (e.g., If you see the letter B you should say B, A, Z, Y, X, etc.). You should try and do this as accurately and as fast as possible and should continue reciting the alphabet until you see a row of asterisks at which time you should recall the reading from the dial face. It is also important to recall the dial reading as accurately as possible. You will earn extra pay for each correct recall that you make and you will lose pay for each error. After the row of asterisks has come on you will have 10 sec in which to recall the dial reading and relax before the word "ready" comes on again signalling the start of a new trial on which a new dial face and a new letter of the alphabet will appear. You should always try and speak the dial reading loudly and clearly so that I can hear you via the two-way speaker system.

There are once again, three different dial faces, so there will be three blocks of trials. I shall be testing how well you remember the dial readings after three different lengths of time. Sometimes you will recite the alphabet for 5 sec before recalling the dial reading; sometimes 10 sec and sometimes 20 sec. This time will be varied from trial to trial. The range on all the dials is from <u>100-300</u>. You will have noticed that on the "clock-face" dial the scale is fixed while the pointer moves round, so that when the pointer is on the right-hand side of the dial the reading must be between 100 and 199. With the "bathroom scales" the pointer stays fixed and the scale moves past the open window. You can

always see two numbers and the numbers increase from left to right. You will have realised that the digital counter unlike the other dials gives you the final digit of the 3-digit number directly.

On each block of trials we shall have two practice trials and then we shall begin the test series. Before each block of trials I shall show you a sample of the type of dial which we shall be using on that block of trials. Please make a recall response on each trial even if you have to guess one of the three digits, and always make the best guess possible - this will help your score. Remember the key thing is once again accuracy. It is very important to recite the alphabet as fast as you can without making mistakes.

Instructions to the third part.--This part is essentially the same as the first part in that you will see a row of asterisks and then a dial face which you must read as accurately as possible. We shall have three short blocks of trials, one for each type of dial with no practice trials.

Experiment III (Spatial Group)

There are two parts to this experiment and you will read the instructions to each part separately and then do that part.

Instructions to the first part.--At the start of each trial you will see a row of asterisks projected on the screen in front of you; this is a warning that a picture of a dial will follow almost immediately. You should fixate this row as the dial will appear in about the same position and this will enable you to read it more accurately. The dial will stay on the screen for 1.5 sec. After the dial appears your task is to read aloud the 3-digit number which is on the dial face (i.e., the dial reading).

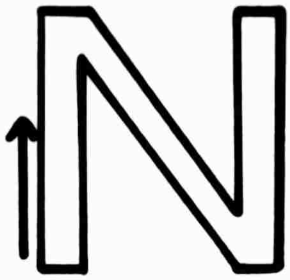
You will have about 10 sec to do this and relax before a row of asterisks will once again appear signalling the start of a new trial on which a new dial will appear. You should always try and speak the dial reading loudly and clearly so that I can hear you via the two-way speaker system in the corner.

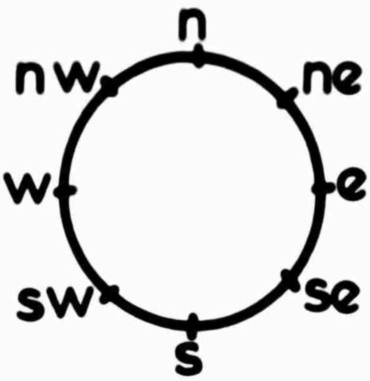
There are three different dial faces which we shall test, constituting three blocks of trials. Before you read a new kind of dial I shall project a sample of it so that you can familiarize yourself with it. The range on all the dials is from 100-300. On each block of trials there will be two practice trials to which you should respond as usual. After these two we shall begin the test series which will consist of eight further trials. You will earn extra pay for each correct reading that you make and you will lose pay for each error, so please try and be as accurate as possible. At the end of each block I shall tell you how well you did on those trials. Remember before each trial to fixate the row of asterisks. Please do not move the chair during the experiment as I should like your eyes to remain a constant distance from the screen throughout the experiment if possible. This means that you should adopt an upright sitting position and try and keep that way during the experiment.

Please make a response on each trial even if you have to guess one or more of the digits, and always make the best guess possible as this will help your score. If the image is ever very fuzzy or grossly out of focus at any time during the experiment please tell me and I shall refocus it. Remember that the key thing in this experiment is accuracy. Any questions?

Instructions to the second part.--At the start of each trial you will see the word "ready" projected on the screen; this is a warning that a picture of a dial will appear in about the same position on the screen and this will help you to read it correctly. The dial will stay on the

screen for 1.5 sec and once again you should read aloud the 3-digit number on the dial face. You should try and do this as fast and as accurately as possible because immediately after the dial disappears a letter of the alphabet will appear. This will be an outline letter and at one of the corners there will be a black spot and an arrow pointing in the direction of an adjacent side of the letter. When the letter comes on your task is to locate the spot, note the direction of the arrow and then you should trace out aloud the letter, starting at the corner where the spot is and going in the direction of the arrow. You should trace out the letter going from corner to corner by using directions of the compass. You should use eight compass directions in all: N, S, E, W, NW, NE, SW, and SE. Assume that any diagonal you meet is along the 45° mark (i.e., NW, NE, SW, or SE). Here is an example. If you see this letter you should say aloud: N, E, SE, N, E, S, W, NW, S, and W.





When you arrive back at the corner at which you started, you should rotate the figure 90° clockwise about that point and once again trace out the figure. Thus with the above letter you should then say: E, S, SW, E, S, W, N, NE, W and S. When you finish this rotate the figure a further 90° clockwise and start again.

You should start tracing out the letter immediately after you have read the dial and do this as accurately and as fast as possible. If you follow these instructions, i.e., set right in and do as well as you can on the tracing you will double your pay for this part of the experiment. You should continue the pattern of tracing out, rotating, tracing out, etc. until you see a row of asterisks at which time you should try and recall aloud the reading from the dial face. After the row of asterisks has come on you will have 10 sec in which to recall the dial reading and relax before the word "ready" comes on again signalling the start of a new trial on which a new dial reading and a new letter of the alphabet will appear. You should always speak loudly and clearly so that I can hear you via the speaker system.

There are once again three different dial faces, so there will be 3 blocks of trials. I shall be asking you to recall the dial readings after three different lengths of time. Sometimes you will trace out the letter for 5 sec before recalling the dial reading; sometimes 10 sec and sometimes 20 sec. This time will be varied from trial to trial. The range on all dials is from 100-300. You will have noticed that on the "clock-face" dial the scale is fixed while the pointer moves round, so that when the pointer is on the right-hand side of the dial the reading must be between 100 and 199. With the "bathroom scales" the pointer stays fixed

and the scale moves past the open window. You can always see two numbers and the numbers increase from left to right. You will have realized that unlike the other two dials the digital counter gives you the final digit of the 3-digit number directly.

On each block of trials we shall have two practice trials and then we shall begin the test series. Before each block of trials I shall show you a sample of the type of dial which we shall be using on that block of trials. Please make a recall response on each trial and within the 10 sec period allotted. It does not matter if you find that you have to guess one or even all of the three digits - just make the best guess that you can. Unlike in the first part of the experiment I shall not be telling you at the end of each block how well you have done on that block. Remember the key thing is once again accuracy. Try your best to trace the letter out as fast as you can without making mistakes. Any questions? One thing to remember also is that I should like you to keep your eyes on the screen at all times especially when you are tracing out the letter so that you stop and recall the dial reading as soon as the asterisks come on. OK?

<u>Instructions to Experiment III (Non-Spatial Group)</u>

There are two parts to this experiment and you will read the instructions to each part separately and then do that part.

<u>Instructions to the first part</u>.--At the start of each trial you will see a row of asterisks projected on the screen in front of you; this is a warning that a picture of a dial will follow almost immediately. You should fixate this row as the dial will appear in about the same position and this will enable you to read it more accurately. The dial will stay on

the screen for 1.5 sec. After the dial appears your task is to read aloud the 3-digit number which is on the dial face (i.e., the dial reading). You will have about 10 sec to do this and relax before a row of asterisks will once again appear signalling the start of a new trial on which a new dial will appear. You should always try and speak the dial reading loudly and clearly so that I can hear you via the two-way speaker system in the corner.

There are three different dial faces which we shall test, constituting three blocks of trials. Before you read a new kind of dial I shall project a sample of it so that you can familiarize yourself with it. The range on all the dials is from 100-300. On each block of trials there will be two practice trials to which you should respond as usual. After these two we shall begin the test series which will consist of eight further trials. You will earn extra pay for each correct reading that you make and you will lose pay for each error, so please try and be as accurate as possible. At the end of each block I shall tell you how well you did on those trials. Remember before each trial to fixate the row of asterisks. Please do not move the chair during the experiment as I should like your eyes to remain a constant distance from the screen throughout the experiment if possible. This means that you should adopt an upright sitting position and try and keep that way during the experiment.

Please make a response on each trial even if you have to guess one or more of the digits, and always make the best guess possible as this will help your score. If the image is ever very fuzzy or grossly out of focus at any time during the experiment please tell me and I shall refocus it. Remember that the key thing in this experiment is accuracy. Any questions?

Instructions to the second part.--At the start of each trial you will see the word "ready" projected on the screen; this is a warning that a picture of a dial will appear almost immediately. You should fixate the word "ready" because the dial will appear in about the same position and this will help you to read it correctly. The dial will stay on the screen for 1.5 sec and once again you should read aloud the 3-digit number on the dial face. You should try and do this as fast and as accurately as possible because immediately after the dial disappears a letter of the alphabet will appear. The letter will stay on the screen for 2 sec. Your task then is to begin immediately to recite the alphabet backwards loudly and clearly, starting with the letter that you see. So for example, if you see the letter H you should say: H, G, F, E, etc. If you come to the beginning of the alphabet you should go to the end and starting reciting backwards again (e.g., If you see the letter B you should say: B, A, Z, Y, X, etc.). You should start reciting the alphabet backwards as soon as you have read the dial face and you should try and do this as fast and as accurately as possible. You will receive extra pay if you follow these instructions and you can double your pay for this part of the experiment if you do this well and set right in reciting as fast and as accurately as you can. You should continue reciting the alphabet until you see a row of asterisks at which time you should try and recall aloud the reading from the dial face. After the row of asterisks has come on you will have 10 sec in which to recall the dial reading and relax before the word "ready" comes on again signalling the start of a new trial on which a new dial reading and a new letter of the alphabet will appear. You should always speak loudly and clearly so that I can hear you via the speaker system.

There are once again three different dial faces, so there will be three blocks of trials. .I shall be asking you to recall the dial readings after three different lengths of time. Sometimes you will trace out the letter for 5 sec before recalling the dial reading; sometimes 10 sec and sometimes 20 sec. This time will be varied from trial to trial. The range on all dials is from 100-300. You will have noticed that on the "clock-face" dial the scale is fixed while the pointer moves round, so that when the pointer is on the right-hand side of the dial the reading must be between 100 and 199. With the "bathroom scales" the pointer stays fixed and the scale moves past the open window. You can always see two numbers and the numbers increase from left to right. You will have realized that unlike the other two dials the digital counter gives you the final digit of the 3-digit number directly.

On each block of trials we shall have two practice trials and then we shall begin the test series. Before each block of trials I shall show you a sample of the type of dial which we shall be using on that block of trials. Please make a recall response on each trial and within the 10 sec period allotted. It does not matter if you find that you have to guess one or even all of the three digits--just make the best guess that you can. Unlike in the first part of the experiment I shall not be telling you at the end of each block how well you have done on that block. Remember the key thing is once again accuracy. Try your best to trace the letter out as fast as you can without making mistakes. Any questions? One thing is to remember also is that I should like you to keep your eyes on the screen at all times especially when you are tracing out the letter so that you stop and recall the dial reading as soon as the asterisks come on. OK?

Experiment IV: Part 1

There are two parts to this experiment; you will read the instructions to each part separately and then do that part.

Instructions to the first part.--This part of the experiment is to study the accuracy with which one can read a dial face which is briefly exposed.

At the start of each trial you will see a row of asterisks; this is a warning that a picture of a dial will follow almost immediately. You should fixate this row as the dial will appear in about the same position and this will enable you to read it more accurately. The dial will stay on the screen for 1.5 sec. After the dial appears your task is to read off the 3-digit number which is on the dial face. You will have about 10 sec in which to do this and relax before a row of asterisks will once again appear signalling the start of a new trial on which a new dial will appear. You should always try and speak the dial reading loudly and clearly so that I can hear you via the two-way speaker system.

There are three different dial faces which we shall test, constituting three blocks of trials. Before you read a new kind of dial I shall project a sample of it so that you may familiarize yourself with it. The range on all dials is from 100-300. On each block of trials there will be eight practice trials to which you should respond as usual. After these eight we shall begin the test series. You will earn extra pay for each correct reading that you make and you will lose credit for each error that you make, so please try and be as accurate as possible. Remember before each trial to fixate the row of asterisks. Please do not move the chair during the

experiment as I should like your eyes to remain a constant distance from the screen if possible. This means that you should adopt an upright position and try and keep that way during the experiment.

Please make a response on each trial even if you have to guess one or more of the three digits, and always make the best guess possible as this will help your score. If the image is ever fuzzy or grossly out of focus at any time during the experiment please tell me and I shall refocus it. Remember the key thing in this experiment is accuracy. Any questions?

Instructions to the second part.--This part of the experiment is to study how well one can remember readings from different dial faces when doing something else.

At the start of each trial you will see the word "ready" projected on the screen; this is a warning that a picture of a dial will follow almost immediately. You should fixate the word "ready" because the dial will appear in about the same position and this will help you to read it correctly. The dial will stay on the screen for 1.5 sec. Immediately after the dial disappears a letter of the alphabet will appear. Your task then is to begin immediately to recite the alphabet backwards loudly and clearly, starting with the letter that you see (e.g., If you see the letter H you should say: H, G, F, E, etc.). If you come to the beginning of the alphabet you should go to the end and start reciting backwards again (e.g., If you see the letter B you should say: B, A, Z, Y, X, etc.). You should try and do this as fast and as accurately as possible and should continue reciting the alphabet until you see a row of asterisks at which time you should recall the dial reading as accurately as possible. You will earn extra pay

for each correct recall that you make and you will lose pay for each error. After the row of asterisks has come on you will have 10 sec in which to recall the dial reading and relax before the word "ready" comes on again signalling the start of a new trial on which a new dial face and a new letter of the alphabet will appear. If you want to change your mind about the number which you recall you may do so within the 10 sec and I shall accept the last number that you give to me. You should always try and speak the dial reading and alphabet loudly and clearly so that I can hear you via the two-way speaker system.

There are once again three different dial faces, so there will be three different blocks of trials. I shall be testing how well you remember the dial readings after three different lengths of time. Sometimes you will recite the alphabet for 5 sec before recalling the dial reading; sometimes for 10 sec and sometimes 20 sec. This time will be varied from trial to trial. The range on all dials is from 100-300. You will have noticed that on the clock-face dial the scale is fixed while the pointer moves round, so that when the pointer is on the right-hand side of the dial the reading must be between 100 and 199. With the "bathroom scales" the pointer stays fixed and the scale moves past the open window. You can always see two numbers and the numbers increase from left to right. You will have realized that the digital counter unlike the other two dials gives you the final digit of the 3-digit number directly.

On each block of trials we shall have two practice trials and then we shall begin the test series. Before each block of trials I shall show you a sample of the type of dial we shall be using on that block of trials.

Please make a recall response on each trial even if you have to guess one of the three digits; and always make the best guess possible--this will help your score.

Remember the key thing is once again accuracy.. It is very important to recite the alphabet as fast as you can without making mistakes. Any questions?

Experiment IV: Part 2

There are two parts to this experiment; you will read the instructions to each part separately and then do that part.

Instructions to the first part.--This part of the experiment is to study the accuracy with which one can read a dial face which is briefly exposed.

At the start of each trial you will see a row of asterisks; this is a warning that a picture of a dial will follow almost immediately. You should fixate this row as the dial will appear in about the same position and this will enable you to read it more accurately. The dial will stay on the screen for 1.5 sec. After the dial appears your task is to read off the 3-digit number which is on the dial face. You will have about 10 sec in which to do this and relax before a row of asterisks will once again appear signalling the start of a new trial on which a new dial will appear. You should always try and speak the dial reading loudly and clearly so that I can hear you via the two-way speaker system.

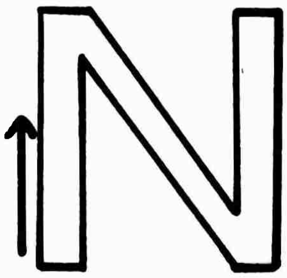
There are three different dial faces which we shall test, constituting three blocks of trials. Before you read a new kind of dial I shall project a sample of it so that you may familiarize yourself with it. The range on

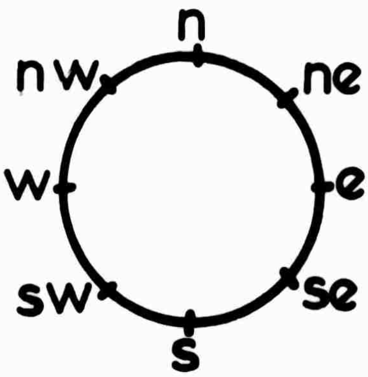
all dials is from 100-300. On each block of trials there will be eight practice trials to which you should respond as usual. After these eight we shall begin the test series. You will earn extra pay for each correct reading that you make and you will lose credit for each error that you make, so please try and be as accurate as possible. Remember before each trial to fixate the row of asterisks. Please do not move the chair during the experiment as I should like your eyes to remain a constant distance from the screen if possible. This means that you should adopt an upright sitting position and try and keep that way during the experiment.

Please make a response on each trial even if you have to guess one or more of the three digits; and always make the best guess possible as this will help your score. If the image is ever fuzzy or grossly out of focus at any time during the experiment please tell me and I shall refocus it. Remember the key thing in this experiment is accuracy. Any questions?

Instructions to the second part.--At the start of each trial you will see the word "ready" projected on the screen; this is a warning that a picture of the dial will appear almost immediately. You should fixate the word "ready" because the dial will appear in about the same position on the screen and this will help you to read it correctly. The dial will stay on the screen for 1.5 sec. Immediately after the dial disappears a letter of the alphabet will appear. This will be an outline letter and at one of the corners there will be a black dot and an arrow pointing in the direction of an adjacent side of the letter. When the letter comes on your task is to locate the spot, note the direction of the arrow and then you should trace out aloud the letter, starting at the corner where the spot is

and going in the direction of the arrow. You should trace out the letter going from corner to corner by using directions of the compass. You should use eight compass directions in all, N, S, E, W, NW, NE, SW, and SE. Assume that any diagonal that you meet is along the 45° mark (i.e., NW, NE, SW, or SE). Here is an example. If you see this letter you should say aloud: N, E, SE, N, E, S, W, NW, S, and W.





When you arrive back at the corner at which you started, you should rotate the figure 90° clockwise about that point and once again trace out the figure. Thus with the above letter you should then say: E, W, SW, E, S, W, N, NE, W, and N. When you finish this rotate the figure a further 90° clockwise and start again.

You should start tracing out the letter immediately after you have read the dial and do this as accurately and as fast as possible. You should continue the pattern of tracing out, rotating, tracing out, etc. until you see a row of asterisks at which time you should try and recall aloud the reading from the dial face. You will earn extra pay for each correct recall that you make and you will lose pay for each error so please try and be as accurate as possible. After the row of asterisks has come on you will have 10 sec in which to recall the dial reading and relaz before the word "ready" comes on again signalling the start of a new trial on which a new dial reading and a new letter of the alphabet will appear. If you want to change your mind about the number which you recall you may do so within the 10 sec and I shall accept the last number that you give to me. You should always speak loudly and clearly so that I can hear you via the speaker system.

There are once again three different dial faces, so there will be three different blocks of trials. I shall be testing how well you remember the dial readings after three different lengths of time. Sometimes you will recite the alphabet for 5 sec before recalling the dial reading; sometimes for 10 sec and sometimes 20 sec. This time will be varied from trial to trial. The range on all dials is from 100-300. You will have noticed that on the clock-face dial the scale is fixed while the pointer moves round, so that when the pointer is on the right-hand side of the dial the reading must be between 100 and 199. With the "bathroom scales" the pointer stays fixed and the scale moves past the open window. You can always see two numbers and they increase from left to right. You will have realized that the digital counter unlike the other two dials gives you the final digit of the 3-digit number directly.

On each block of trials we shall have two practice trials and then we shall begin the test series. Before each block of trials I shall show you a sample of the type of dial which we shall be using on that block of trials. Please make a recall response on each trial even if you have to guess one of the three digits, and always make the best guess possible - this will help your score.

Remember the key thing is once again accuracy. It is very important to trace out the letter as fast as you can without making mistakes. Any questions?

APPENDIX II

TABLED VALUES FOR DATA CITED IN CHAPTERS III, IV, V AND VI

TABLE 1

PERCENT READING ERRORS IN EXPERIMENT I

	Dial Face					
	Moving Scale			Moving Pointer		
Exposure Duration (sec)	0.75	1.0	1.25	0.75	1.0	1.25
6 Female Ss	12.18	7.05	5.77	19.77	13.46	5.77
6 Male Ss	5.77	5.77	3.85	10.90	4.49	3.21
All Ss	8.97	6.41	4.81	15.38	8.97	4.49

TABLE 2

PERCENT CORRECT RECALL OF DIAL READINGS FROM DIFFERENT DIALS AT DIFFERENT RETENTION INTERVALS - EXPERIMENT II

	Retention Interval (sec)		
	5	10	20
Dial Face			
Moving Scale	57.3	56.8	49.0
Moving Pointer	70.3	57.3	48.4
Digital Counter	65.1	70.8	56.8

TABLE 3

PERCENT CORRECT RECALL OF READINGS FROM THE VARIOUS DISPLAYS - EXPERIMENT III

	Spatial Interpolated Task Retention Interval (sec)		
	5	10	20
Moving Scale	67.4	54.2	45.8
Moving Pointer	69.4	56.9	54.2
Digital Counter	76.4	61.8	59.0

	Non-Spatial Interpclated Task Retention Interval (sec)		
	5	10	20
Moving Scale	63.9	50.7	39.6
Moving Pointer	66.7	58.3	46.5
Digital Counter	66.0	57.6	54.9

TABLE 4

PERCENT CORRECT RECALL OF THE READINGS FROM THE VARIOUS DISPLAYS - EXPERIMENT IV

	Non-Spatial Interpolated Task		
	Retention Interval (sec)		
	5	10	20
Moving Scale	50.0	41.67	37.50
Moving Pointer	55.21	40.63	53.13
Digital Counter	72.92	61.46	55.21

	Spatial Interpolated Task		
	Retention Interval (sec)		
	5	10	20
Moving Scale	67.71	51.04	44.79
Moving Pointer	66.67	62.50	52.08
Digital Counter	69.79	61.46	62.50

TABLE 5

ERROR CLASSIFICATION DATA OBTAINED WITH THE DIGITAL COUNTER

	Experiment II		
	Retention Interval (sec)		
	5	10	20
V_1	3	0	3
V_2	4	5	9
S	19	21	21
M	12	12	14
L	29	18	36

	Experiment III		
	Retention Interval (sec)		
	5	10	20
Spatial Interpolated Task			
V_1	0	1	0
V_2	3	3	3
S	13	11	17
M	6	20	13
L	12	20	26
Non-Spatial Interpolated Task			
V_1	0	2	1
V_2	3	7	2
S	21	16	23
M	16	14	18
L	9	22	21

TABLE 5 (Continued)

ERROR CLASSIFICATION DATA OBTAINED WITH THE DIGITAL COUNTER

	Experiment IV		
	Retention Interval (sec)		
	5	10	20
Non-Spatial Interpolated Task			
V_1	1	0	0
V_2	3	5	5
S	5	10	9
M	4	2	6
L	13	20	23
Spatial Interpolated Task			
V_1	2	0	0
V_2	7	6	2
S	12	8	11
M	3	10	8
L	5	13	15

APPENDIX III

ANALYSIS OF VARIANCE FOR EXPERIMENTS I, II, III AND IV

TABLE 1

ANALYSIS OF VARIANCE FOR THE SQUARE ROOT TRANSFORMATION OF THE NUMBER OF READING ERRORS - EXPERIMENT I

Source of Variation	df	MS	F
Dial Face	1	0.74	4.63*
Error for Dial Face	11	0.16	
Exposure Duration	2	2.25	11.25***
Error for Exposure Duration	22	0.20	
Dials x Exposure Duration	2	0.425	
Error for Dials x Exposure Duration	22	0.245	

* $p < 0.1$

*** $p < 0.01$

TABLE 2

ANALYSIS OF VARIANCE FOR ERROR DATA $\frac{M + 1/2}{M + L + 1}$ - EXPERIMENT II

Source of Variation	df	MS	F
Dial Face	1	0.69	17.25***
Error for Dial Face	23	0.04	
Retention Interval	2	0.01	
Error for Retention Interval	46	0.05	
Dial Face x Retention Interval	2	0.05	1.02
Error for Dial Face x Retention Interval	46	0.049	

*** $p < 0.01$

TABLE 3

ANALYSIS OF VARIANCE FOR ERROR DATA $\frac{M + 1/2}{M + L + 1}$ - EXPERIMENT III

Source of Variation	df	MS	F
Between Subjects			
Interpolated Task	1	0.08	
Subjects Within Groups	17	0.15	
Within Subjects			
Dials	1	0.25	3.68
Error for Dials	34	0.068	
Dials x Interpolated Task	1	0.01	
Error for Dials x Interpolated Task	34	0.068	
Retention Interval	2	0.135	3.46**
Error for Retention Interval	68	0.039	
Retention Interval x Interpolated Task	2	0.025	
Error for Retention Interval x Interpolated Task	68	0.039	

** $p < 0.05$

TABLE 4

ANALYSIS OF VARIANCE FOR ERROR DATA $\frac{M + 1/2}{M + L + 1}$ - EXPERIMENT IV

Source of Variation	df	MS	F
Interpolated Task	1	0.02	
Error for Interpolated Task	11	0.0209	
Dials	1	0.85	12.44***
Error for Dials	11	0.069	
Retention Interval	2	0.19	6.74***
Error for Retention Interval	22	0.028	
Interpolated Task x Dials	1	0.38	16.10***
Error for Interpolated Task x Dials	11	0.0236	
Interpolated Task x Retention Interval	2	0.005	
Error for Interpolated Task x Retention Interval	22	0.0218	
Dials x Retention Interval	2	0.11	2.657
Error for Dials x Retention Interval	22	0.0414	
Interpolated Task x Dials X Retention Interval	2	0.01	
Error for Interpolated Task x Dials x Retention Interval	22	0.035	

*** $p < 0.01$

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